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SOIL SURVEY MANUAL

By

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Bureau of Chemistry and Soils

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CONTENTS

INTRODUCTION

This manual is intended for the use of soil surveyors in the field, particularly those engaged on projects of, or cooperative with, the Bureau of Chemistry and Soils of the United States Department of Agriculture. Its present form and content reflects the development

of the work over the last 38 years and the ideas and labor of hundreds of soil scientists [1] working in the field during this period.

Although soil science has developed rapidly during the last few years, it is still a young science with a rapidly changing nomenclature. As the science has progressed, new terms have come into use. A few have been taken from other languages, but many have been taken out of the body of our own language and given particular meanings, or at least have had special significances attached to them. Naturally there has been confusion, as scientists in various localities, and even different scientists in the same locality, have not used the terms uniformly. The same confusion exists now in the field of economics and did exist in other sciences during similar periods of development.

It is essential that the nomenclature and terminology be as uniform as possible. In the compilation of the present work, every effort was made to use and define terms as specifically as possible, according to the most commonly accepted usage, realizing at the same time that certain claims might have been made for other usages. Thus a certain amount of almost arbitrary selection has been necessary.

Similarly, there must be some standardization of method in order that the work may be correctly interpreted everywhere. At the same time the method itself must be sufficiently flexible that not only all types of soils and landscapes may be mapped with scientific accuracy and practical effectiveness and expediency, but that new ideas for improvement may be developed.

Because of possible present errors and certain future development, there will need to be corrections and changes. It is hoped that errors and omissions will be called to the attention of the author for inclusion in any subsequent editions.

PURPOSE OF A SOIL MAP AND REPORT

The objects in soil surveying are (1) to determine the morphology of soils, (2) to classify them according to their characteristics, (3) to show their distribution on maps, and (4) to describe their characteristics, particularly in reference to the growth of various crops, grasses, and trees. The ultimate purpose is to provide accurate soil maps, necessary for the classification, interpretation, and extension of data regarding agricultural production, the classification of rural lands, and for the factual basis in the development of sound programs of rural land use, whether planned by public or private agencies, or by individuals.

The soil map is designed to show the location and extent of the various kinds of soil in an area with sufficient detail of categorical definition and of cartographic expression to indicate those differences significant to man in using the land for the growth of plants. Although the soil survey provides an inventory for soil resources, this feature is not its principal contribution. Primarily it serves as a basis for classifying the results of experience and experiments regarding the

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[1] Special credit should be acknowledged to the following who have assisted directly in the preparation of the manuscript: J. Kenneth Ableiter, Mark Baldwin, W. T. Carter, W. E. Hearn, Macy H. Lapham, J. W. McKericher, C. C. Nikiforoff, and T. D. Rice, all of the Soil Survey staff. Many other scientists have made contributions. Descriptions of symbols for base maps and other parts of the strictly engineering phases of the work have been taken from instructions issued by the U. S. Geological Survey with the necessary modifications.

characteristics and use-capabilities of soils, in order that this information may be applied to each individual unit of operation. It is helpful to know the exact acreage of each soil type, but of far more vital importance to soil research and its application is the accurate knowledge of the soil types on each farm and the pattern which they make in respect to one another and to the farm unit. Thus, the determination and mapping of soil types is an essential and integral part of any soil research program, particularly in its applied phases.

As the entire agricultural enterprise is intimately related to the nature of the soil, an accurate soil map, together with its accompanying report, must be considered as a handbook of the agricultural geography of the area. For the United States as a whole, even though the nature of the soil, considering its inherent productivity for adapted crops as well as its responsiveness to management, is by far the dominating factor in determining the agricultural production of an area, it must be recognized that other factors have an influence; and especially to the extent that these additional factors are physical, it is necessary that the soil survey include them, in order that the ultimate practical objective of the work may be fully realized.

Although the fundamental purpose of the work is to serve practical objectives, it must necessarily be based on sound scientific principles. If such principles are violated, of course the work loses its scientific value and its practical value as well. Thus not only is the work directed toward a practical objective, but it is at the same time oriented by a scientific foundation and objective. On the basis of the results of the soil survey, problems in ecology, geography, and other sciences are enlightened, since by their very nature soils constitute an expression of the physical and biological forces of the landscape in their totality.

Before the actual work begins in an area the purpose of the survey must be clearly defined. Naturally the same detail in differentiation is not required in all landscapes nor for all objectives. For example, in an area suited generally to some extensive use, such as grazing or forestry, less detail in the differentiation of types and phases may be required to reach the objective of the project as compared to a survey in an area generally adapted to intensive cultivation. Not only the nature of the landscape but also the definite objective of the project may influence the field techniques. For example, a soil survey to be used as the basis of assessment for taxation will necessarily need to recognize all factors influencing production in some detail, in many instances in more detail than would be necessary for determining general adaptation of crops and systems of soil management.

CLASSIFICATION AND EXTENSION OF AGRICULTURAL DATA

The basic physical fact fundamental to all agriculture is the relationship between the plant root and the soil in which it grows. Broadly speaking, there is on the one hand the capability of the soil and on the other the requirements of the plant. In order that a satisfactory adjustment may be achieved, there are two general approaches: (1) The changing of the soil through various techniques which man may employ to fit the requirements of some particular plant or group of plants; and (2) choosing plants to fit the soil as

nature has determined it. People, of course, employ both methods, with extreme intensive agriculture on the one hand, as in the greenhouse, and extreme extensive agriculture on the other hand, as in the farm wood lot or on the range. A knowledge of the requirements of the plant and a knowledge of the capabilities of the soil are essential for this adjustment to be made with the greatest benefit to the individual operator and to society as a whole.

Such knowledge is accumulated through experimentation and experience. The results of experiments and of observation must be classified in some way, in order that they may be understood and their significance determined; and at the same time there must be some device whereby these results can be given geographic extension. It is known that experimental results in one place do not necessarily apply to some other place. It is known that the experience of one farmer gained on one soil frequently cannot be duplicated by the same farmer on another soil. In the matter of fertilizer recommendations, both the requirements of the plant and the nature of the soil are important. In order to make proper recommendations of fertilizer applications, it is necessary to obtain data and experience from known soils and extend the information gained to the same soils. Many other examples of a similar nature could be cited in regard to techniques other than fertilization, such as liming, drainage, irrigation, terracing, and cultivation, as well as agronomic recommendations of crops to be grown and similar matters.

Therefore, the most important purpose of the soil map is to indicate the fundamental land types that can be described accurately as such, and the capabilities for use of which can be defined through the interpretation of experimental data and experience. Having defined these types, knowledge regarding them can be extended if their location is shown on maps. A soil map by itself may have little practical significance to the layman; but when the agricultural information regarding the soil types shown on the map is classified and brought together in the accompanying report, the ultimate objective of the work may be reached. Similarly, the results of experiments on land, no matter how carefully obtained, are of little practical use unless these results can be extended expeditiously and accurately to the people actually using the land. These data must be classified and, as the soil type represents the summation of all the forces operating to produce the medium in which the plant grows, it is the logical basis on which these results may be classified; and with the distribution of the soil types shown on maps their extension can be made easily and directly.

RURAL LAND-USE PLANNING

Rural land-use planning, in a broad sense, refers to provisions, made by the exercise of forethought, for some definite land-use pattern, either by individuals or groups. To a considerable degree, the success of one farmer compared with that of another, is determined by the extent to which he can and does exercise sound forethought in planning his farming operations for the use of land. The soil survey, and for that matter all agricultural research, is predicated on the assumption that forethought is and will be exercised in planning land use.

As the expression, "rural land-use planning", is commonly used, however, reference is made to the collective efforts of a social group to formulate ways and means, in the form of policies and programs, for the attainment and maintenance of those uses of land which will, over a long period, best serve the general welfare. Specifically, the establishment of county zoning ordinances by citizens, in order to prohibit injurious or undesirable structures and uses of land and structures, or to encourage the using of land in particular ways in the interest of the public welfare, is a typical example. Such ordinances or other devices encouraging the particular uses of land in the public interest may have one or several objectives, according to the nature of the land in the area and the local problems to be met. For example, in the interest of flood control or for the conservation of water and soil, particular land uses may be encouraged, in order to prevent excessive run-off and soil erosion.

Frequently the problem to be met is one of local taxation. Extensive agriculture may be discouraged on soil unsuited for crop production because the land cannot support the expensive schools, roads, and other necessities of such a community life. Citizens or communities located in such areas may become serious charges on other communities if engaged in farming on land of poor quality for this use. On the other hand, this same land may be well able to support the costs attendant to the community organization when devoted to forestry or grazing. Many other examples could be cited, but these are sufficient to illustrate the type of problems that may face certain rural communities.

Basically, of course, the problems relate directly to the physical nature of the land, and particularly to the capabilities of the soil. Nevertheless every area has individual local physical and economic problems. The relative importance of the various phases of the landscape vary, and in many instances local problems dictate special emphasis on particular features. For example, the relative importance of such factors as degree of slope, stoniness, depth to rock or a water table, or condition of highways varies greatly in different sections of the country.

Frequently an important factor determining the best use of an area or of an individual farm unit is not only the nature and relative total percentages of the soil types, but also the manner in which they are associated with one another. For example, in a hill-valley section frequently good cropland and land suited only to pasture are so mixed that the latter may be used to good advantage in a farm unit having some good cropland, without which a different use, such as forestry or extensive grazing, might be more desirable. Many parts of the country well adapted to dairying have this intimate association of good cropland and land suited to pasture but not to crops. Similarly, the presence of a small acreage of soil suitable to certain cash crops may be responsible for a thriving farm unit, whereas the same area of land without this small percentage of one particular kind of soil might make an undesirable farm unit or even be unsuited to farming at all. The presence of as much as 10 acres of certain soil types may fundamentally influence the use of well over 100 acres of other soil types.

The present pattern of land use naturally has an influence on any recommendations for use. Certain soils are intermediate be-

tween those naturally best suited to cropping, on the one hand, and some less intensive use, such as forestry or grazing, on the other. If the land is undeveloped agriculturally, it might be considered best that it be devoted to the more extensive use, whereas if the area has already been improved by roads, houses, schools, and other buildings, it may be considered best that it remain in the more intensive use. Also the location of nonagricultural communities, such as industrial or recreational centers, may markedly influence the use of rural land, especially that of naturally medium or low productivity for crops.

It is the purpose and the function of the soil survey to map the soils and other physical features of the land in a manner such that these problems of land-use planning can be solved rationally in the best interests of the individual or social groups responsible for their solution. Having defined and mapped the soils according to the physical differences significant in their use, their use-capabilities and their important differences must be ascertained and clearly brought out in the accompanying report. Soil types (or land types) must be determined on the basis of their physical characteristics, but agronomic and economic data are of invaluable use in arriving at their capabilities. For example, one cannot make a suitable map of land on the basis of tax delinquencies, but data regarding tax delinquencies, when classified according to soil types, may be suggestive regarding their capabilities for use.

Since maps showing the location of the soil types, together with accurate descriptions of the capabilities of these types, form the basis for the most effective planning of rural land use, it is necessary that those in charge of soil-survey parties study the problems of their areas, particularly from the point of view of the objectives of the survey. At the same time great care must be taken that some transient or locally prominent conditions are not overstressed and that some less commonly recognized factors are not overlooked. The soil survey is basic to many phases of agricultural production and economy. Features that may appear to be of little importance at the moment may develop later to be of greater importance. The soil surveyor must be very careful not to overstress or understress various aspects of the work, but he must bear in mind that the survey must meet the immediate objectives and at the same time meet the requirements of a fundamental soil survey, basic to all agriculture and of permanent usefulness.

RURAL LAND CLASSIFICATION

The application of the results of the soil survey is frequently made through the intermediate step of some sort of land classification. Such a classification may involve little more than a grouping of the soil units shown on the map into land classes according to their common natural characteristics or according to their productivity for specific crops or groups of crops; it may involve the grouping of soil units into classes according to their recommended use, considering present economic conditions and the fundamental physical factors; or it may involve such complete detail as that required for placing a rating on each social unit (farm, ranch, etc.) for purposes of tax assessment.

The general problem of classification is to place the items classified into suitable categories, the better to study and remember their characteristics, and to show their interrelationships. A natural land classification can be defined as one in which the natural land types are placed in categories according to their inherent characteristics. The most important factor defining the natural land types is the soil, but also included are climate, relief, stoniness, and vegetation. It is realized that the soil is itself a reflection of the influences of these factors, but their detailed expression may involve more precise definition than would be practical by considering the soil profile alone. Such a natural classification of land types is analogous to other strictly scientific classifications similar to those in current use for plants and animals. Frequently, however, a classification of direct applicability to some practical problem may need to be modified, in order that certain specific features of great practical importance be given the correct emphasis in reference to the practical problem at hand.

A land classification according to use capabilities can be defined as one in which bodies of land are classified (on the basis of physical, or both physical and economic considerations) according to their capabilities for man's use, with sufficient detail of categorical definition and cartographic expression to indicate those differences significant to man. Such a land classification may be looked on as "practical" in contrast to the "natural", or more strictly scientific classification. The natural classification is of extreme scientific interest and importance and, like other scientific systems of classification, must necessarily form the ground work for any land classification according to use capabilities, devised to meet some immediate practical objective. Whereas in a natural classification immediate use must not dictate its construction, in one devised to meet some definite practical objective the practical aspects of the work are of the utmost importance. Until the objective is clearly defined, there can be no thoroughly satisfactory pragmatic classification.

All land that is used can be classified in six rather definite use groups, and, in addition, two others are important but commonly combined with one or more of the first six: (1) Cropping, (2) grazing, (3) forestry, (4) recreational, (5) mining, (6) urban development, (7) wildlife preservation, and (8) protection (land used to prevent injury to water supplies or to other more valuable land). In addition there may be added occasional combinations, such as forest-recreational, grazing-cropping, and especially forestry-wildlife preservation, urban-protection, and forestry-protection. There are, of course, some areas of land having little or no capability for use and are therefore waste land.

The determination of the use of land and its comparative capability, in a social and economic sense, within any use group, depends on more than its inherent physical qualities of climate, soil, relief, stoniness, and native vegetation. Although these factors dominate the classification and are of basic importance, economic, social, and geographic factors, such as accessibility to markets,[2] proximity to other land of similar and other uses, local and world demand for various products, and location in respect to water supply, are vital

[2] In part this factor is an outgrowth of the physical quality of the land, as lines of transportation have sought the good land.

considerations. Whereas the principal physical components of the natural land type are essentially permanent, these other factors are necessarily transitory.

Native vegetation is, of course, subject to change by man, and, except as it serves as an aid to the interpretation of the significance of physical qualities, would be only an element in the classification of undisturbed land types. Minor changes in stoniness and relief can be made by man. Other important changes may be brought about by irrigation and drainage. Soil erosion may bring about modification of the soil types (or natural land types), especially but not exclusively, where land naturally suited only to grasses or trees has been used for crops. Where these changes have been introduced, the definition of the mapping units must take cognizance of them for purposes of a land classification according to use capabilities. Such mapping units will usually represent phases of the fundamental soil type.

The basic physical data must be kept clearly separated from transitory economic considerations. If the physical data are once accurately mapped, revisions in the land classification can be made easily as economic conditions change, but if not, any revision requires that all the work, including the field mapping, be done again.

The purpose which the land classification is to serve may be of a general (schematic) nature, such as the broad, regional planning of land development, or the detailed classification of lands for rural zoning or for tax assessment may be contemplated. There is more and more public demand for the detailed classification. For this purpose, the unit of classification must be small enough to allow the accurate rating of individual units of production in the social units of land (farms, ranches, etc.).

LAND CLASSIFICATION

1. Objective: Classification and extension of data regarding land; planning of land utilization.

(Detailed expression also furnishes basic physical classification for objective under 2.)

Climate. Soil. Relief. Stoniness. (Vegetation).	Natural land type. To be classified into categories according to relative physical capability in possible types of utilization.

2. Objective: Rural zoning; tax assessment.

Natural land types (detailed expression). Relationship to social groups. (*a*) Economic. (*b*) Social.	Social land unit. To be classified: (1) Into use groups:

- (*a*) Cropping.
- (*b*) Grazing.
- (*c*) Forestry.
- (*d*) Recreational.
- (*e*) Mining.
- (*f*) Wildlife preservation.
- (*g*) Protection.
- (*h*) Urban.

or definite combinations:

- (*i*) Crop-grazing.
- (*j*) Crop-urban.

(2) As to capabilities within the use group.

No attempt will be made here to lay out detailed directions for a method[3] to be used in different regions for various objectives, but in order that the soil surveyor may have clearly in mind the general requirements for such a method applicable to areas where the cropping, forestry, and grazing use groups are concerned, a brief summary of the steps involved in a detailed land classification to meet the objectives of rural zoning or tax assessment is outlined as follows:

(1) The first essential includes the accurate mapping, in detail, of the physical features of the land. The basic data are those regarding the soils that are mapped in accordance with the modern system of soil classification. Cognizance is also taken of relief, stoniness, native vegetation, and any other physical features of local importance in land use. These may be regarded as the external characteristics of the soil type. Combinations of these features give the natural land types which can be assigned definite ratings of productivity in the various use groups. In order that these natural land types may be interpreted in accurate terms, it is essential that the maps show sufficient detail, both as to definition of the categories and as to cartographic expression. *Individual land types of a size sufficient to influence significantly the capabilities of separate units of operation need to be separated.*

(2) Coincident with, or subsequent to, the mapping of the natural land types, the inherent productivity, including "responsiveness" to cultural practices, of these types must be determined in each of the possible use groups. The ratings should not reflect transitory economic considerations but should be based on the essentially permanent physical factors of productivity. These ratings must represent the generalization of all information available, including that obtainable inductively considering the nature of the land, and that acquired deductively from analyses of practical experience and experimentation. Conveniently these ratings of each land type may be expressed in terms of percentage of a standard, taken as the best land, from a physical point of view, in each of the use groups.

(3) The next step in the procedure is the determination of the use group for each tract of land. Especially in areas that have been settled for many years this determination will be made largely on the basis of the physical qualities of the natural land types. Other factors, such as accessibility to markets and the size of contiguous areas of similar land types will also be important, especially in a new or rapidly changing section. For example, an area having a natural land type ever so well-suited to cropping cannot be placed in the cropping use group, should the area be too small for a unit of operation or isolated from other land suitable for cropping. This and similar considerations make it necessary sometimes to place land naturally suited to crops in the forestry or grazing use groups, and subsequently the land must be rated in that use group.

(4) Finally, each social unit of land is rated in the use group (or use groups) in which it belongs. The ratings of the natural land types within the use groups are basic, but these need adjustment according to economic or geographic considerations which may influence production on these social units. Such considerations include

[3] For specific references, see Bibliography, p. 134.

accessibility to markets, nature of the existing vegetation on forest and grasslands, and similar factors. By an analysis of production on the standard or ideal land, and the marketing costs at various distances on the different classes of roads, a schedule may be prepared showing the percentage reduction in the basic rating of the land for various locations. Similar schedules may need to be calculated in respect to the other factors.

As a final result, each piece of land can be given a rating in terms of the percentage of the standard for the area or region. If the classification is then used for purposes of tax assessment, the proper local officials need to place an appraisal value on the standard land, and every piece of land in the area takes its appraisal value strictly in accordance with its productive capacity. Ratings given by such a land classification need to have added to them an appraisal of buildings and improvements for loan purposes or for tax assessment where such improvements are taxed. It must be emphasized again that the physical data should be kept separated from the economic, including the basic ratings of the natural land types; as a result of any changes in economic conditions, the necessary adjustments of the ultimate land classification can be made easily without additional field work.

This brief statement of the requirements of a rural land classification emphasizes the importance of the objective. The data to be obtained in the course of the soil survey depend upon the purposes the maps and reports are to serve. Many of the items will not be included, and time must not be taken for mapping detail beyond that required for the objective.

OTHER USES

Although the chief practical purposes of the soil survey have been discussed, attention should be directed briefly to certain other uses not specifically included. Such an investigation as the modern soil survey, providing data on the physical qualities of the land as a medium for the growth of plants, naturally could be expected to serve many incidental purposes. It is perhaps unnecessary that attention be drawn specifically to the great contributions of the work to soil science, as scientific investigations are a necessary prerequisite to the construction of the soil map itself. In such related fields as geography, the contributions of the work should be obvious since these data provide the very basis of agricultural geography. Probably no other work has contributed more to the field of ecology, because the soils themselves owe many of their most important characteristics to the influence of the native vegetation with which they have developed, and because a knowledge of the ecology of crop plants is one of the principal objectives of the work.

An accurate base map is necessary for the construction of a soil map. Where such maps are not available, the soil surveyor must construct them. In areas where heretofore no adequate road maps or drainage maps were available, these features of the soil maps have been of great value to public officials and other citizens as well as to military, sanitary, and civil engineers, and others. Although the soil map is neither a geological map nor primarily concerned with geology as such, in the absence of detailed maps, especially of surface geology, the soil maps are frequently very useful in locating deposits of gravel, sand, clay, peat, marl, and

similar materials. By proper interpretation many features of glacial geology and the nature of the surface rocks can be outlined from the soil map.

Soils and the materials underneath vary greatly as to their suitability as foundations for buildings and as subgrades for hard-surfaced roads. Soil maps are valuable in the selection of proper sites and in planning an adequate type of construction. Soil maps made directly for these purposes need to stress particular features and the nature of the underlying material more than the ordinary soil map and must be made in greater detail for best results. In the absence of such detailed investigations much that is helpful can be obtained from the modern detailed soil map, even though the map is not made with this objective directly in view.

Other practical problems may be solved in part, or important leads disclosed, through the use of these data, such as the corrosion of various metals and the durability of variously treated woods in soils of different character. The soil maps have already been useful in choosing locations for pipe lines.

CHARACTER OF THE SOIL MAP AND REPORT

The objectives of the soil-survey map and report have been discussed briefly, and before explaining in detail how such maps are made the map itself must be described. As discussed throughout this publication, the soil map refers to a map showing soil types (defined later), and not to maps showing simply single soil characteristics, such as acidity, texture, or erodibility. Supplemental maps showing these or other single features can be made, by interpretation, from the soil map, since these qualities are included in the definition of a soil type.

As the soil maps and reports are made through the use of techniques conditioned by the state of our scientific knowledge in order to reach certain objectives, their form is dynamic and not static or changeless. Soil science has made unusually rapid progress during the last few years, and improved techniques are constantly being developed. These are reflected as improvements and changes in the soil maps and reports. Further, as American agriculture has developed, the problems to be solved have changed. Specifically, more detailed and precise information regarding soils is required as a basis for the solution of problems involving rural land use and crop adjustment. Naturally the character of the soil maps has reflected this interest. For example, when investigating a new, more or less undeveloped area, schematic maps that can be produced rather rapidly, in order to show the general location of lands suitable for farming, are needed. In a general way such information now exists for nearly all of the United States. But the present land problems are definitely concerned with the important differences of soil within a community and even on single farms. Soil maps useful for this purpose must necessarily show significant differences with considerable detail.

DEFINITION OF A SOIL MAP

A soil map is a representation on paper designed to portray the distribution of soil types and phases, as well as other selected cultural and physical features of the earth's surface necessary for con-

venience in its use. Depending upon the detail with which the boundaries between the soil types are plotted, three kinds of soil maps are recognized. Of these the detailed soil survey is the most useful and the most commonly made.

DETAILED SOIL MAP

On a modern detailed soil map the boundaries between soil types and phases are plotted upon the base map in detail from observations made throughout their course; in addition to such physical features as lakes and streams, important variations in others of significance in land use, such as relief and stoniness, are shown; and all significant cultural features, helpful in determining specific locations, such as ditches, roads, houses, and public buildings, are plotted accurately. The soil types and phases shown on the detailed soil map are defined so as to indicate the mappable differences of significance in rural land use. Although small variations, due to management for example, where not accompanied by mappable physical differences, are not shown, responsiveness to management practices can be interpreted from the map, as such responsiveness is itself a definite function of the soil type. In making a detailed soil map in ordinary terrain, the land is traversed at intervals of one-quarter mile.

RECONNAISSANCE SOIL MAP

On a reconnaissance soil map the boundaries between the soil types and phases are plotted from observations made at intervals and not throughout their course as on the detailed soil map. The mapping units are defined similarly to those shown on the detailed soil map but with less preciseness, particularly of the phases, as only the more prominent features can be used in drawing the boundaries. These maps vary rather widely in scale and degree of detail from those made by traverses at approximately 6-mile intervals to those made by traverses at one-half mile intervals which approach the detailed soil survey in completeness and specificity. The base maps of the less detailed reconnaissance surveys may show only the location of railroads, towns, large lakes and streams, and similarly prominent features, whereas others are nearly as complete as the detailed soil map. Occasionally the reconnaissance maps which closely approach the detailed maps have been styled "semidetailed soil maps." The degree of detail is determined by the nature of the land and its probable use, and the time available for the work. In mountainous regions or other areas not likely to be devoted to intensive uses, traverses are made at less frequent intervals than on land of more suitable character for farming. Many of the detailed soil maps made in the early days of this work in the United States would be considered reconnaissance soil maps at present.

DETAILED-RECONNAISSANCE SOIL MAP

Such a soil map has portions mapped according to the requirements of a detailed soil map and portions according to the less rigid requirements of a reconnaissance soil map. The parts of the area covered by the two types of survey are indicated by an appropriate small sketch map on the margin of the soil map. The county is the usual unit of a soil survey. In such units, and even where some other basis is used for establishing a unit of survey, frequently large

areas of land obviously unsuited to an intensive agricultural use are included. In instances of rough mountainous land, large expanses of acid peat land, stony desert land, or similar types of land unsuited to farming, it is frequently unnecessary that the survey be carried out in the detail necessary for a detailed soil map. Such areas are mapped in reconnaissance and published with the portion mapped in detail on the same soil map.

FIELD AND PUBLICATION SCALE

Ordinarily, detailed and detailed-reconnaissance soil maps are published on a scale of 1 inch to 1 mile,[4] although a few have been published on other scales. Reconnaissance soil maps are published on the minimum scale necessary to show the information plotted on the field sheets. Ordinarily these maps are published on a scale varying from 1 inch to 2 miles to 1 inch to 6 miles. Most of the few being published at present are on the former scale. Certain schematic soil maps compiled by generalizing more detailed information are published on smaller scales, depending on the purposes for which the maps are intended.

As a general rule the field mapping is done on a larger scale than that used in publication. Currently, most of the detailed soil surveys are being made on a scale of 2 inches to 1 mile. In a few instances a field-mapping scale of 2.64 inches to the mile (1 inch to 2,000 feet) is used where base maps are available on this scale. Aerial photographs on still larger scales are used where they are available and can be used to advantage. Except in areas of unusual uniformity it is ordinarily not practical to use a field scale of less than 2 inches to 1 mile for detailed surveys. If an accurate base map is available and the soil mapping is performed by surveyors of unusual skill in drafting, detailed soil maps can be made on the scale of 1 inch to 1 mile if the soils are not particularly complex. Under ordinary circumstances, however, such a scale is inadequate for mapping with the necessary detail and precision. Areas having close culture should not be mapped on a scale less than 2 inches to 1 mile, even though the principal mapping is on a smaller scale.

Maps made on a large scale in the field can be reduced to 1 inch to 1 mile for publication. *It must be stressed, however, that soil maps made in the field should not be enlarged.* If the maps made in the field are not on a scale large enough for some particular use, their enlargement does not increase their utility, however much it may appear to do so. If a useful soil map is needed on a large scale it must be made on this scale, or still larger, in the field.

Highly detailed soil maps necessary for detailed land classification and land-use planning, especially of complex landscapes, cannot always be reduced to a scale of 1 inch to 1 mile without dropping out some of the detail. In certain instances it may be necessary and practical to publish the soil map on a scale larger than 1 inch to 1 mile. Ordinarily the increased value of the map will not justify the much greater expense involved in publication. Maps do not always need to be published in large editions to be highly useful for

[4] Maps made at exactly this scale have the ratio 1 to 63,360. The U. S. Geological Survey topographic quadrangles are usually published on a scale of 1 to 62,500, and where such topographic maps are available the Soil Survey uses the base data and publishes on this same scale which also is considered to be 1 inch to 1 mile. In other areas, where the soil surveyors make their own base maps, the soil maps have a scale of 1 to 63,360.

certain purposes. The field sheets can be photographed and copies mounted by hand work, in order that enough showing all the detail may be made available for the use of those requiring them. Many detailed soil maps on a very large scale are needed for special purposes. For certain types of land-use planning and for detailed ecological studies, it may be necessary to employ a field scale of mapping as great as 8 inches to 1 mile in extremely complex areas. In useful and practical studies of soils, in order to indicate their relative suitability for highways or other structures, scales as great as 25 or even 50 inches to the mile may be essential. Sufficient copies of such maps can be made by photographing, black-and-white etching, and by other ways, if the expense of a lithographed map would be out of proportion to its superior usefulness.

The determination of the exact scale to be employed in field mapping in order to reach the objective of the survey thus depends on several variables: (1) The degree of differentiation necessary, both as to the variations between soil types and phases and as to the size of areas of one type lying within another, in order to reach the objective of the work, is a factor of first consideration. In the ordinary detailed soil survey of rural lands the relative intensity of use is an important factor in determining the detail necessary to reach the objective. (2) The natural complexity of the landscape, especially in relationship to the capabilities of the soil for use, will be important. (3) The scale of any existing accurate base map must be considered. If an area is undertaken for survey and there is already available a recent accurate base map, the same scale should be employed if it is practical to do so. (4) The experience and skill of members of the surveying party will determine necessarily to some extent the scale employed. Skillful and experienced soil surveyors, thoroughly familiar with the techniques of mapping, can map satisfactorily on a smaller scale than less experienced workers. Necessarily the scale must be adequate for the least skillful of the mapping party.

NATURE OF A SOIL-SURVEY REPORT

The soil-survey report which accompanies the soil map describes the area surveyed, the characteristics and capabilities for use of the soil types and phases shown on the map, and the principal factors responsible for soil development. It is an integral part of the complete publication and not simply an adjunct to the soil map. Except as a base map, the soil map without the report is of little use to persons unfamiliar with the specific nomenclature employed. First of all, the report contains a complete description of the soil types shown on the map and their relationship to one another. As the objective of the work is to provide information directly relating to the agricultural use of the land, those characteristics of importance in the use of the soil for the growth of plants is stressed.

Much of this information is obtained by observation during the course of the survey, but by no means exclusively so. Climatic, chemical, economic, agronomic, and all other data bearing on the nature and capabilities of the soil from other sources are used to the extent that such information is available and can be interpreted in relationship to the soil types occurring in the area. To the extent that the location of the soil areas in respect to markets and similar factors

have an important bearing on the use of the soils, these relationships are identified and discussed. The soil surveyor must be certain to make careful notes during the course of the survey and to acquaint himself with other useful data presently available, in order that the report and map together may be a complete handbook of the agricultural geography of the area.

PREPARATIONS FOR FIELD WORK

Field work is undertaken for the purpose of accomplishing some objective in a definite area. The larger part of the survey projects of the Soil Survey Division of the Department of Agriculture involve cooperation with some local agencies, such as the State agricultural experiment stations, which in turn frequently cooperate with other interested State or county agencies. The personnel of a survey party frequently consists, therefore, of employees from one or more cooperating organizations. Cooperative projects are undertaken after agreement by the agencies concerned as to the objectives of the work, personnel to be assigned, and similar matters. The Soil Survey Division is responsible for the technical details of the work and usually, but not always, a Federal employee is designated as chief of the survey party. Before actual field work is undertaken, the chief of the party must acquaint himself with the objectives of the work, including the wishes and interests of any cooperating agencies. (1) He will be given a letter of authorization and other instructions regarding the work; (2) he must assemble all available cartographic data of assistance in preparing the base map and soil map; and (3) he must be certain that each surveyor has the necessary equipment and supplies for the work.

INSTRUCTIONS AND PERSONNEL

Each employee of the Soil Survey Division of the United States Department of Agriculture will receive a letter of authorization and other instructions, on being assigned to a soil-survey project. Additional directions may be given him from time to time as necessary. The chief of the soil-survey party is responsible for all the work of the party, including the preparation of the necessary reports, and individual surveyors will receive their instructions from him. The chief of the party is responsible to the regional inspector or his assistant, within whose district the area is located, for technical directions regarding all phases of the work (fig. 1). The regional inspector, or his delegated assistant, will visit the area at the time of its initiation or shortly thereafter, in order to assist the chief of the party in constructing a proper legend of soil separations. *Before any plotting of soil boundaries is started, each surveyor in the party must be furnished with a complete descriptive legend, describing, quantitatively and qualitatively, the use of all symbols of whatever kind placed on the map.* The construction of such a legend will be explained later.

The chief of the field party will need to exercise careful judgment in the disposition of assistants in accordance with the objectives of the work, the nature of the mapping problems, and the previous experience of the workers. The simplest party is composed of two

workers, the chief of party and an assistant, but frequently much larger parties must be organized, usually in pairs with an autotruck for each pair. In heavily wooded country and similarly undeveloped areas, where there are few roads, it may be practical to assign three or even four workers with one truck. The party chief will designate leaders for each group, according to their technical and administrative ability.

In large parties, it is of the utmost importance that the chief of party work in the field with each group frequently, especially in the beginning of the work. Unless the party is very large, it is best to keep the men together in one headquarters, in order that daily contacts may be possible, and to move the headquarters at frequent intervals. *The party should never be divided in the beginning of the work.* If certain parts of the area must be mapped by groups in side camps, the surveying should be planned in such a way that this

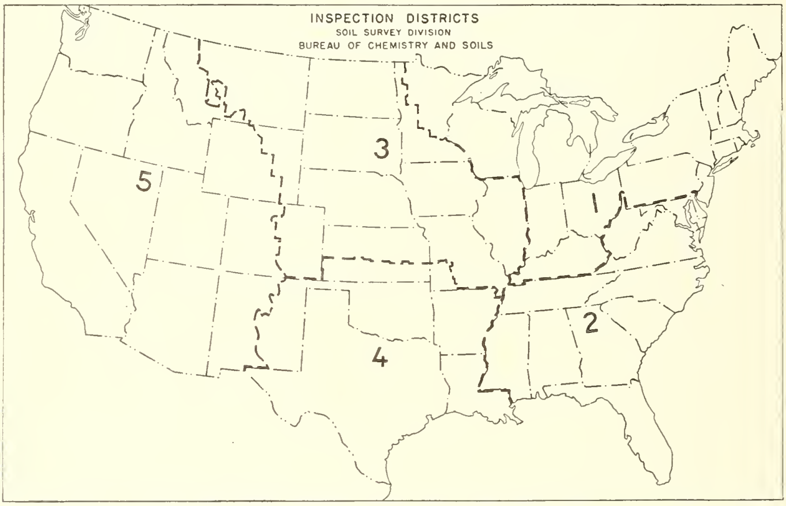

FIGURE 1.—Outline map showing the inspection districts of the Soil Survey Division as of September 1, 1937.

work will not be undertaken at the start but after the surveyors already will have had considerable experience in mapping under the close supervision of the party chief. Each area has its own peculiar problems, and the party chief must first scout the area as a whole and later make such disposition of his assistants as will be most efficient in point of time and expense and at the same time insure complete uniformity of mapping.

Nearly every survey party will have one or more inexperienced men. Although these men have had training in soil science, they have yet to learn the techniques of soil surveying. All the steps involved in the work must be explained to them carefully and repeatedly, but it must be remembered that they learn mostly by doing. At first all their work must be carefully checked and corrected in their presence so that they may understand their errors. Later they can do individual work where it can be carefully checked with that of experienced men. That such assistants may be of the maximum use-

fulness, careful judgment is required in order not to underestimate or overestimate their progress and development. Ordinarily, a new man who is well trained in fundamental soil science will be able to cover nearly as much ground as an experienced man, after a few months of intensive training and close guidance, provided he has daily contact with an experienced surveyor.

Especially with large parties of 10 to 15 workers much of the time of the party chief necessarily must be devoted to these duties, preparation and revision of the mapping legend, and obtaining the necessary data for the soil-survey report. Each worker or group of workers should be given definite assignments drawn on an outline map of the area. Each should color the area completed on the progress map as the work progresses, in addition to making detailed written reports in square miles. It is necessary to have such an up-to-date progress map, in order to plan the work with the greatest efficiency and prevent overlapping or omissions.

The chief of party must give close attention to the rate of progress, which will be influenced by the nature of the country, the detail necessary, and the skill of the surveyors. Any instances of incompetence or inattention to duty must be reported promptly if they cannot be corrected. Usually slow rates of progress are due to faulty understanding of the mapping legend or of mapping techniques and can be corrected easily by an observing, tactful party chief. To discover and correct these difficulties, it is necessary for the leader to work in the field with his assistants from time to time. It must be emphasized that careful planning of the work is necessary, to insure satisfactory progress. For example, short delays of a large party, of either the field mapping or the inside work, are due to poor planning by the chief of party, and they constitute serious and unnecessary handicaps to progress.

Plans must be laid in advance for periods of inclement weather, in order that the necessary inside work can be accomplished when field work is impractical. Such duties consist of obtaining data from records and from interviews with county officials, farmers, and others, for usé in the soil-survey report, and of checking the field sheets. Occasionally, and especially in the arid regions, it will be necessary to do some office work during fair weather, but for the most part, cold, rainy, or otherwise unsatisfactory days for field work can be utilized most advantageously for the inside work.

ASSEMBLY OF AVAILABLE CARTOGRAPHIC DATA

Immediately after approval has been obtained for the soil survey of a county or area, all available map data must be assembled for use of the field party. Some of the more important classes of such data are listed as follows:

United States Geological Survey topographic quadrangles for as much of the area as has been surveyed. These maps may be on the scale of 1:24,000, 1:31,680, 1:62,500, or 1:125,000. Those on the scale of 1:62,500 and of comparatively recent issue are especially recommended for use as base maps for mapping the soils in detailed areas. These may be photographed to the scale desired and prints furnished according to the needs of the party. Such maps

may be mounted as one sheet or cut and mounted on cloth to meet the requirements of the field work.

Aerial photographs are available for certain areas, and advantage should be taken of them by the field party even though the entire area is not covered. Where such photographs are used, especial care must be taken to insure sufficient control for their proper adjustment.

Maps published on various scales by the War Department, such as river surveys, lake surveys, and others made by the Corps of Engineers are available for parts of the country.

Land Office township plats (G. L. O. plats) on a scale of 2 inches equal 1 mile are available for sectionized country, and copies should be obtained.

Post office rural delivery maps (scale 1 inch equals 1 mile) and any special maps issued by other Federal map-making agencies, such as the nautical charts of the Coast and Geodetic Survey, are helpful.

Soil maps of adjoining counties and tracings or photographs of field sheets of unpublished adjacent areas should be available.

The locations and descriptions of all triangulation control stations established by the United States Coast and Geodetic Survey, United States Geological Survey, and United States Corps of Engineers, including transit-traverse stations, must be obtained at the beginning of the survey.

Local county road maps are frequently available from the county or State highway departments.

Any base maps considered for use in soil surveying should be critically examined for suitability and accuracy in detail.

EQUIPMENT AND ITS CARE[5]

Care must be taken that each man has the proper equipment for the duties assigned to him. It is, however, unnecessary that every man have a complete outfit to meet every condition which may arise, although the party as a whole will need to be so prepared. For example, it is unnecessary that every man in a large party have a square-pointed spade for use in collecting soil samples. In an area consisting largely of open country, where most of the work is done on plane tables, it is not necessary that every man have an additional forester's or geologist's compass suitable for making traverses in places where the use of a plane table is impracticable, but, of course, at least one such compass should be available to the party as a whole.

For the detailed soil survey in ordinary terrain, the following is a list of necessary equipment. Each man will need certain items according to the nature of the work he is required to perform.

Accurate speedometer for each car.
Accurate tire pressure gage.
Round-pointed spade of a type to suit particular conditions.
Square-pointed spade.
Pick.
Soil auger, with extension.

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[5] Reasonable care must be taken to protect Government property, and all instances of claims for lost, stolen, or broken equipment must be presented immediately with a full explanation. Frequently the party chief will need to obtain equipment for the use of his assistants, and in such instances, he should get signed receipts from them and be certain that everything is accounted for at the close of the season or before they are released.

Plane table, with compass, tripod, and case.
Alidade, with case.
Hand level (Abney).
Compass, forester's or geologist's.
Geologist's hammer.
Tally counter.
Triangles.
Straightedge.
Protractor.
Surveyor's band chain.
Rule (6-foot).

In certain areas the following additional equipment will be needed:

Peat sampler.
Electrolytic bridge and accessories.
Soil-reaction test kit.
Sundial compass.

The following supplies should be available:

Notebooks.
Pencils (4H, 6H, and 9H).
Acid, hydrochloric.
Fine needles.
Thumbtacks.
Ink (waterproof, blue, black, red, and yellow).
Colored pencils.
Paper (plane-table and tracing).
Pens (crow-quill and drawing).
Erasers (ink and pencil).
Sacks and tags (for soil samples).
Printed forms and stationery.

SPEEDOMETER

The speedometer used for measuring distances in soil surveying is not greatly unlike that in common use on ordinary automobiles and trucks, except that it is constructed to give more accurate readings. One row of figures gives miles, tenths, and hundredths, and the other row gives miles, fifths, fiftieths, and five-hundredths. Naturally such a measuring device must operate directly from the front wheel and not from the drive shaft as with ordinary automobiles. Every car used in soil surveying must be equipped with this device, even in areas where base maps are available.

In equipping the late-model cars with this special speedometer the following general procedure is suggestive.

(1) Remove the right front wheel and take off the brake drum.

(2) Bore out on a lathe the ring gear to a size between 0.015 and 0.005 inch smaller in diameter than the outside of the brake drum. This is to allow for shrinkage on the brake drum. Caution: The drum may be larger near the flange.

(3) Heat the ring gear to an even cherry red all over and place it upon the brake drum, tightly against the brake-drum flange. The drum and wheel can be assembled and replaced. It will be necessary to readjust the brake.

(4) Drill a hole one-half inch in diameter in the brake housing 2 inches back from the front center (fig. 2, *A*). Cut stud blot, leaving the end which the clamp fits 1¼ inches long. Continue the 7/16–14 thread through the entire stud. Fasten the stud to the brake drum housing by means of a 7/16-inch cap screw three-fourths of an inch long, using a lock washer (fig. 2, *A*). To make the assembly for attaching the fiber gear give the angle bar no. 4007 a 45° twist (cold) anticlockwise. Thread the angle bar with ¼-inch pipe tap and screw ¼-inch ell and 4-inch nipple to this so that angle bar and nipple are parallel (fig. 2, *B*). Figure 3, *A* shows the right position of the assembly to mesh with the ring gear shrunk on brake drum. The clamp may need a wider slot to allow it to fit the ¼-inch pipe nipple.

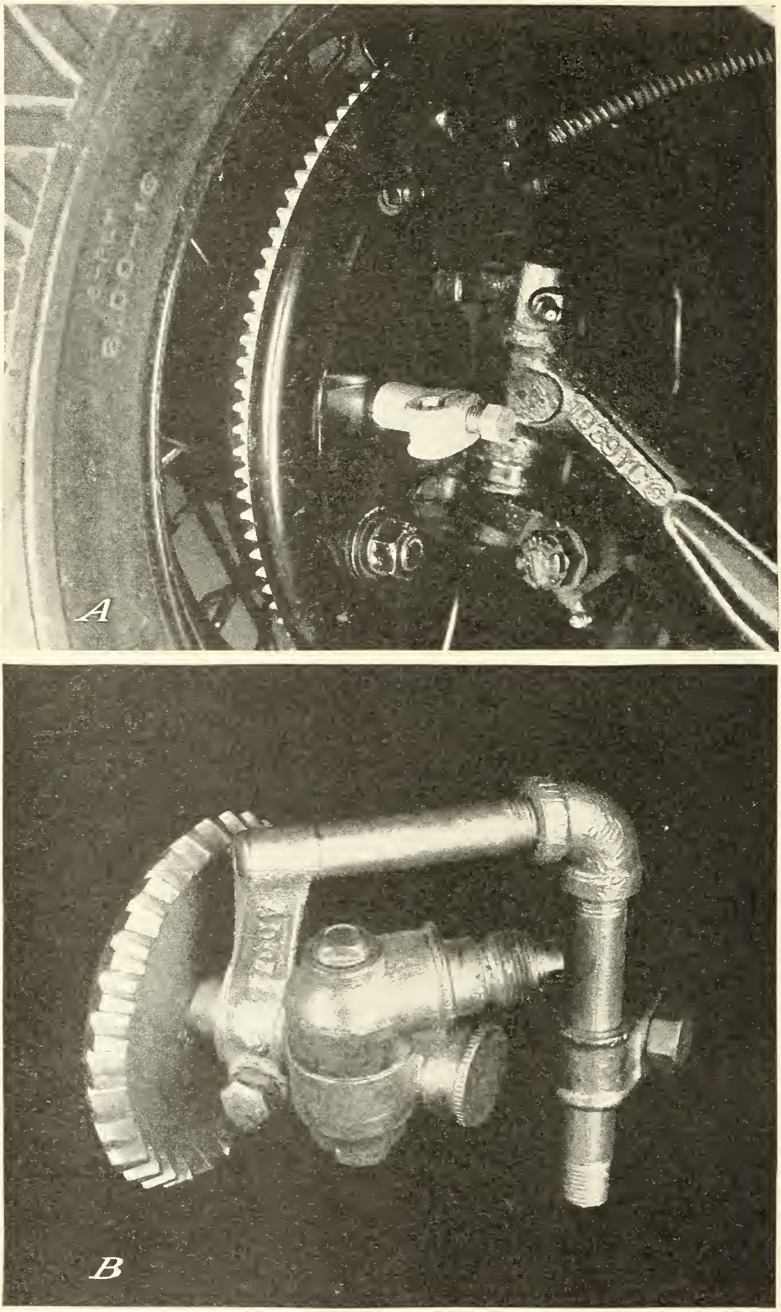

FIGURE 2.—*A*, The stud bolt in position on the brake housing; *B*, the assembly for attaching fiber gear after twisting angle bar 4007.

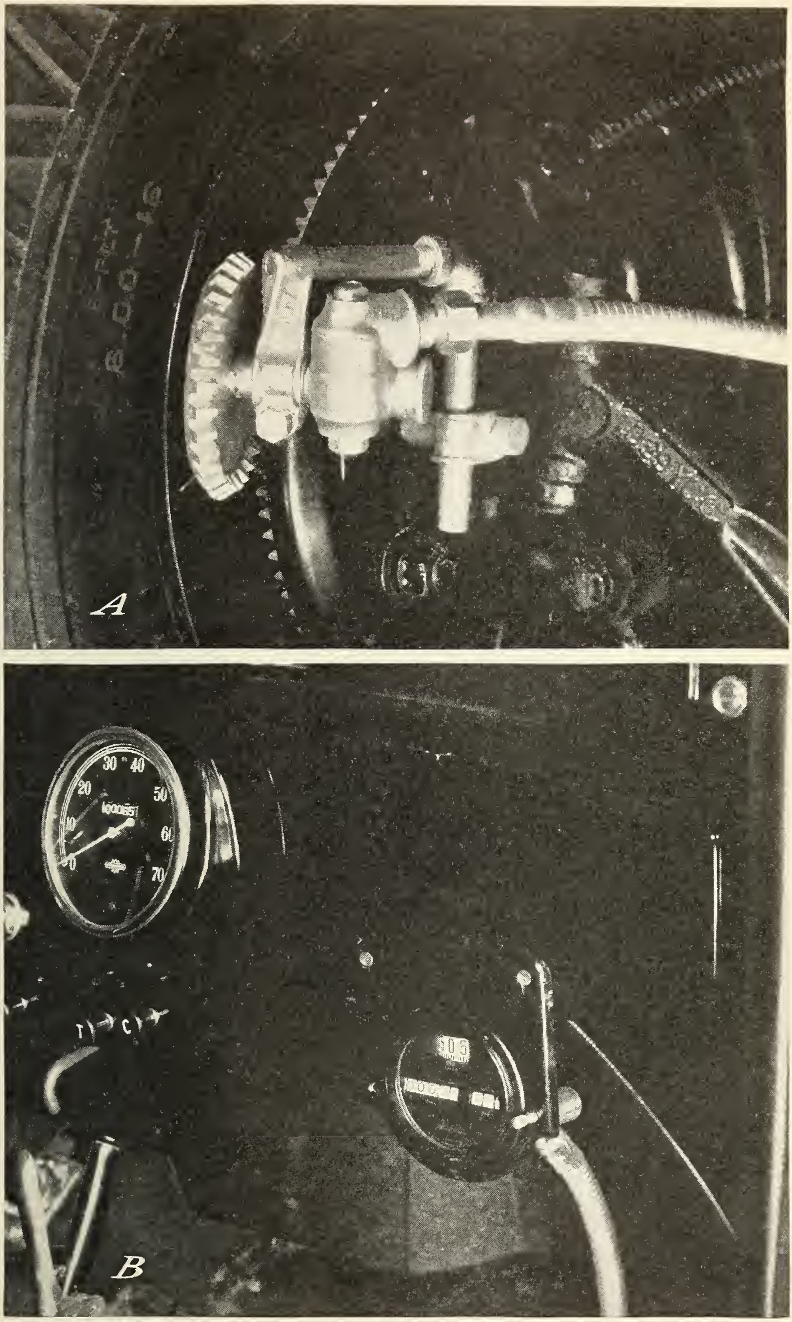

Figure 3.—*A*, Complete assembly in correct position for operation. By loosening the clamps on the end of the stud bolt, the fiber gear may be disengaged while the speedometer is not needed. *B*, Speedometer head in correct position on the dash.

(5) Mount the speedometer head on the dash near the right side; the upper two screws will be sufficient to hold speedometer in place. Run the cable from the swivel joint between the front springs and through a 1-inch hole in the floor board below the mounted speedometer and make connections to the speedometer head. Figure 3, *B* illustrates the correct position of the head.

(6) Put the fiber gear on the swivel joint, mount and adjust the assembly as shown in figure 3, *A*.

The size of tire and brake drum govern the speedometer parts needed, in order that the correct readings will be obtained. As the styles of autos change, the procedure for attaching the speedometer will need to be varied somewhat.

Adjustment and care.—After the speedometer has been roughly adjusted by the proper choice of gears, final adjustment must be made by varying the tire pressure. Along some road convenient to headquarters an exact mile should be laid off with a surveyor's steel tape and conspicuous stakes set, in order that the tire pressure may be adjusted conveniently until the speedometer gives an exact reading. This pressure can be noted and the tire maintained uniformly at that pressure. Since the pressure required to give a correct reading gradually changes as the tire ages, at least weekly checks need to be made against the standard mile.

It must be noted further that under certain circumstances a rather sudden change in the air pressure of the tire may occur and thereby lead to inaccurate measurements. If, for example, one is working on dirt roads in the cool of the morning and later in the day drives out on a hot pavement, the tire pressure will need to be adjusted. Errors due to slippage are likely to occur on slippery roads or loose gravel or sand, and while roads are in such conditions accurate measurements cannot be made by this method. Variations in load also influence tire pressure.

These speedometers need careful oiling. The gears in the head may get out of adjustment from time to time and need repairing, in order to prevent locking and the subsequent breaking of the cable. Both the cable and fiber gear are subject to considerable wear, and care should be taken that extra parts are on hand for an emergency. The fiber gear should be disengaged by tilting it away from the drive sprocket and the equipment not allowed to operate unless actually needed for measurements.

It is realized, of course, that measurement by the use of such a speedometer, even under the best conditions, is not so precise as more costly and time-consuming methods. Yet with care this equipment is entirely satisfactory for soil surveying in all ordinary terrain that is not too hilly or where the roads are not extremely winding or crooked, and especially where definite control points can be located accurately on the field sheets.

PLANE TABLE AND ACCESSORIES

In soil surveying a rather simple plane table or traverse board is used, as shown in figure 4. Essentially, this instrument consists of a drawing board, usually 15 by 15 inches, supported by a tripod. The board is oriented by means of a compass [6] placed in a notch at one side, which is, of course, subject to the same errors as any other

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[6] In areas having magnetic attraction such that the plane table cannot be oriented in the usual way by the magnetic compass, the Baldwin solar chart may be used. For an explanation of its use and for other refinements in engineering techniques, see Beaman (*1*).[7] A copy of this important manual should be in the hands of every soil surveyor.

[7] Italic numbers in parentheses refer to Bibliography, p. 134.

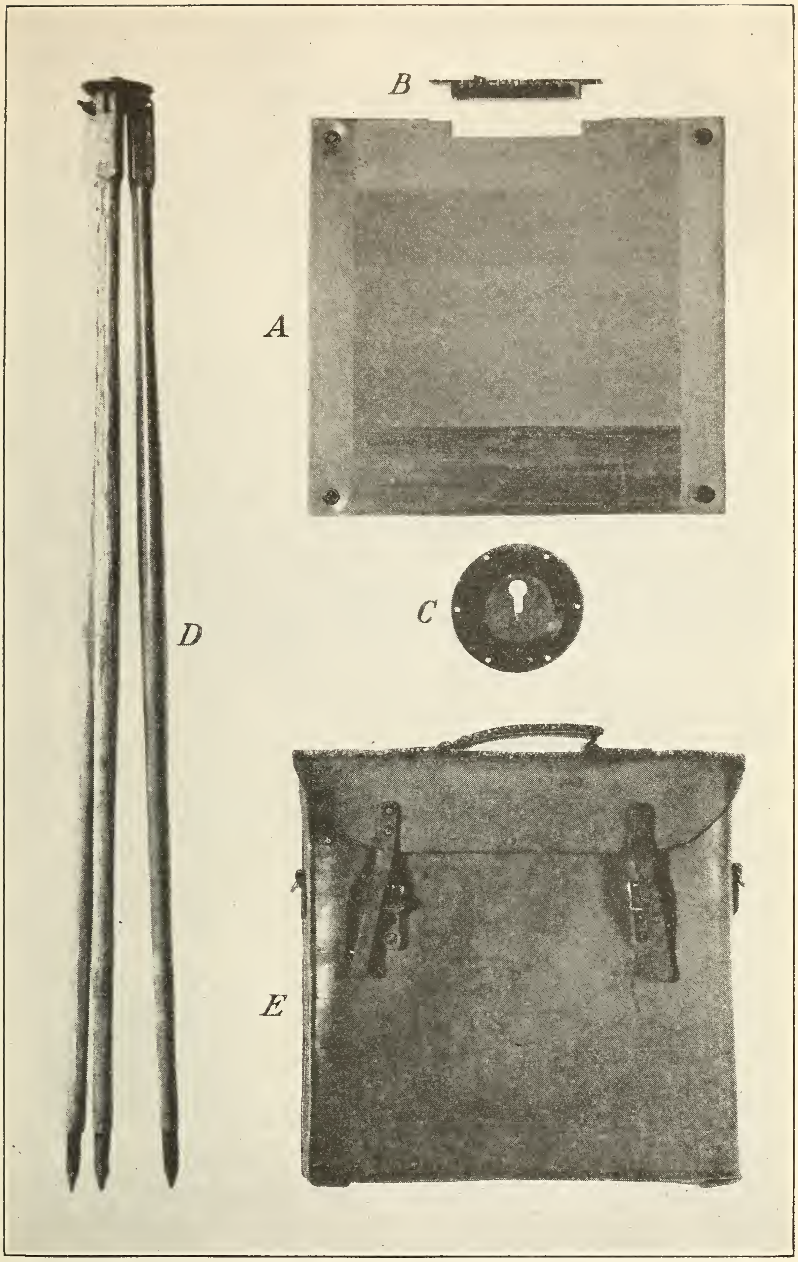

FIGURE 4.—Plane table, unassembled: *A*, board; *B*, compass; *C*, head; *D*, tripod; and *E*, case.

compass. Especially in sectionized areas where the magnetic declination is very great, it may be necessary to set the compass in the board at an angle in order that a full township, 36 square miles, may be included on one field sheet on the scale of 2 inches to 1 mile.

To the bottom of the board there is screwed a brass plate by which the board is fastened to the tripod with a spring and thumbscrew. Except when in actual use, the board, together with the map under construction, is kept in a leather case. The board should be placed in the case with the compass at the top, and care must be taken always to place the board in the case in the same way, in order that the maps may not be soiled by rubbing against leather discolored by the metallic plate. Usually the board is inserted in the case with the map toward the buckles. The plane-table case should never be used for carrying metallic notebooks or other equipment likely to discolor the leather.

A high quality of special drawing paper mounted on cloth is used for mapping. Such paper is cut into squares slightly smaller than the plane-table board and held in place by four thumbscrews in the four corners of the board. The best results are obtained by using flat paper. If the supply has been received in rolls, the sheets should be placed between flat surfaces and pressed before using. If the paper does not lie flat on the board, small brass thumbtacks may be used on the margins. Great care must be taken in order to mount the paper so that it is tight. The thumbscrews are slightly sunken, but when freshly mounted in fair weather it should not be necessary to turn the thumbscrews in the entire way to have the paper tight. The paper will be inclined to buckle during unusually moist conditions, and it can be tightened by turning the thumbscrews all the way down. With extreme changes in weather conditions some tendency to buckle must be expected, but the skillful surveyor can keep this to a minimum through care, especially in mounting the paper.

While in use in the field, the plane-table sheet should be protected by cover paper as much as practicable, in order to reduce its exposure to a minimum. Medium dull-brown wrapping paper is suitable and reduces the glare on bright sunny days.

The plane table in common use is made approximately level by adjusting the position of the tripod (fig. 5). After firmly establishing the tripod and orienting the board by the compass, great care must be taken that the plane table is not disturbed. The surveyor must not lean against it. Care must be taken also to avoid any magnetic attraction, such as steel culverts, railroad tracks, power lines, or other steel equipment. Pocketknives and similar objects must not be brought near the needle. Only brass tacks and fittings should be on the board itself. The compass needle should never be released except when in actual use.

Alidades.—The most satisfactory alidade for ordinary work is one made from a flat boxwood chain scale with two beveled white celluloid edges, fitted with folding sights and graduated into fiftieths of an inch (fig. 6). Where such a special scale in the field is used as 1 inch to 2,000 feet, alidades especially graduated should be provided. The alidade should be carried in a leather case and not used for office work. Care must be taken that the edges do not become dented.

FIGURE 5.—Plane table assembled for use.

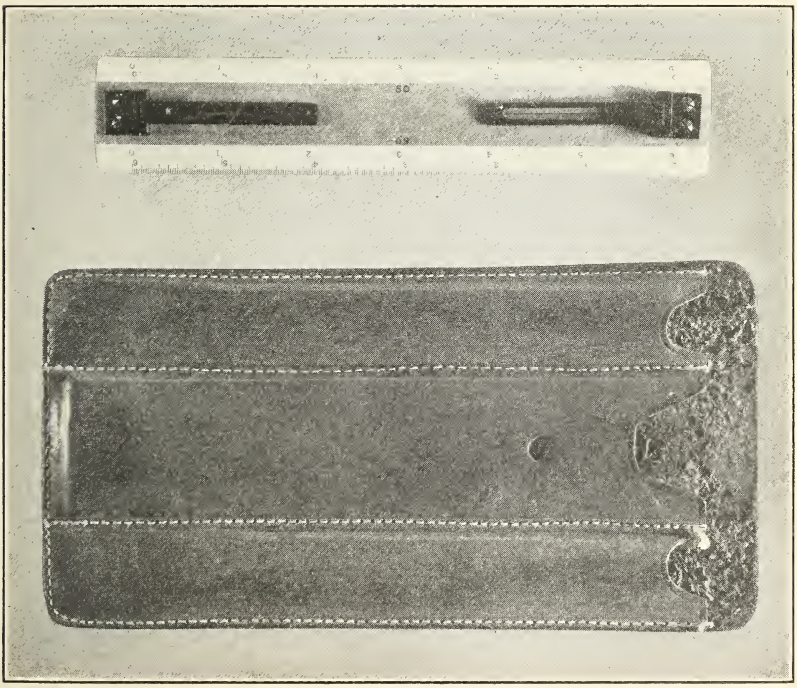

FIGURE 6.—Alidade with case.

The station occupied is located and a fine sharp-pointed needle, fitted with a wooden cap, is pressed into the paper. The edge of the alidade is placed against the needle and a sight taken by rotating the alidade, keeping it tightly against the needle until the two sights of the alidade are directly in line with the distant object. With the alidade held down firmly on the paper, a fine line is drawn with a hard, sharp pencil from the needle toward the object. The length of the line is determined by the measured distance. No line longer than the compass needle should be finally plotted from one sight.

Mounting partial maps on the plane table.—Other maps, such as base maps or partly completed soil maps, may be placed on the board by brass thumbtacks. The plane table is oriented carefully by the compass in some known position shown on the map from which a distant known point, also shown on the map, is clearly visible. A faint line is drawn between the two points and the alidade kept carefully parallel with this line. The map is placed in approximate position and lightly fastened by one tack in one corner and then rotated carefully until the alidade is sighted directly on the distant object. The map then may be fastened firmly by additional brass thumbtacks. When constructing a base map, the sheet should not be removed until the primary traverse is completed and preferably not until the entire field work is essentially completed.

COMPASSES

The most commonly used compass is the one fitted into the plane table. Frequently, however, as in heavily wooded areas and especially for short foot traverses, the plane-table compass cannot be used as conveniently as other types of compasses. The compass next most commonly used is the forester's or geologist's compass shown in figure 7, *A*. For short secondary traverses this compass is held in the hand, but for more accurate work a Jacob's staff must be used as a support. Simple box compasses or other less precise instruments are not satisfactory for soil-survey work.

Compasses are delicate instruments and must be handled carefully. It must be a strict rule with all types of compasses that the needle be lifted from the center pin immediately after use. Especially a compass must never be moved from one place to another with the needle resting on the center pin.

Upon entering a new area the compass will frequently be found to be out of adjustment. The sliding weight on the needle must be moved if the needle is so out of balance that one end touches the glass cover of the box when leveled. The forester's compass should be set in respect to the magnetic declination so that readings can be taken directly in respect to true north, thus obviating the necessity of making individual corrections after each reading.

The sundial compass.—The sundial compass most commonly used in soil surveying resembles the forester's compass, except that a string extends from the top of the rear sight to the opposite side of the box and a sundial is provided on the margin (fig. 7, *B*). This compass cannot be used in the hand but must be well supported by a Jacob's staff. The instrument is fitted with a compass needle similar to that of the ordinary forester's compass, such that it can

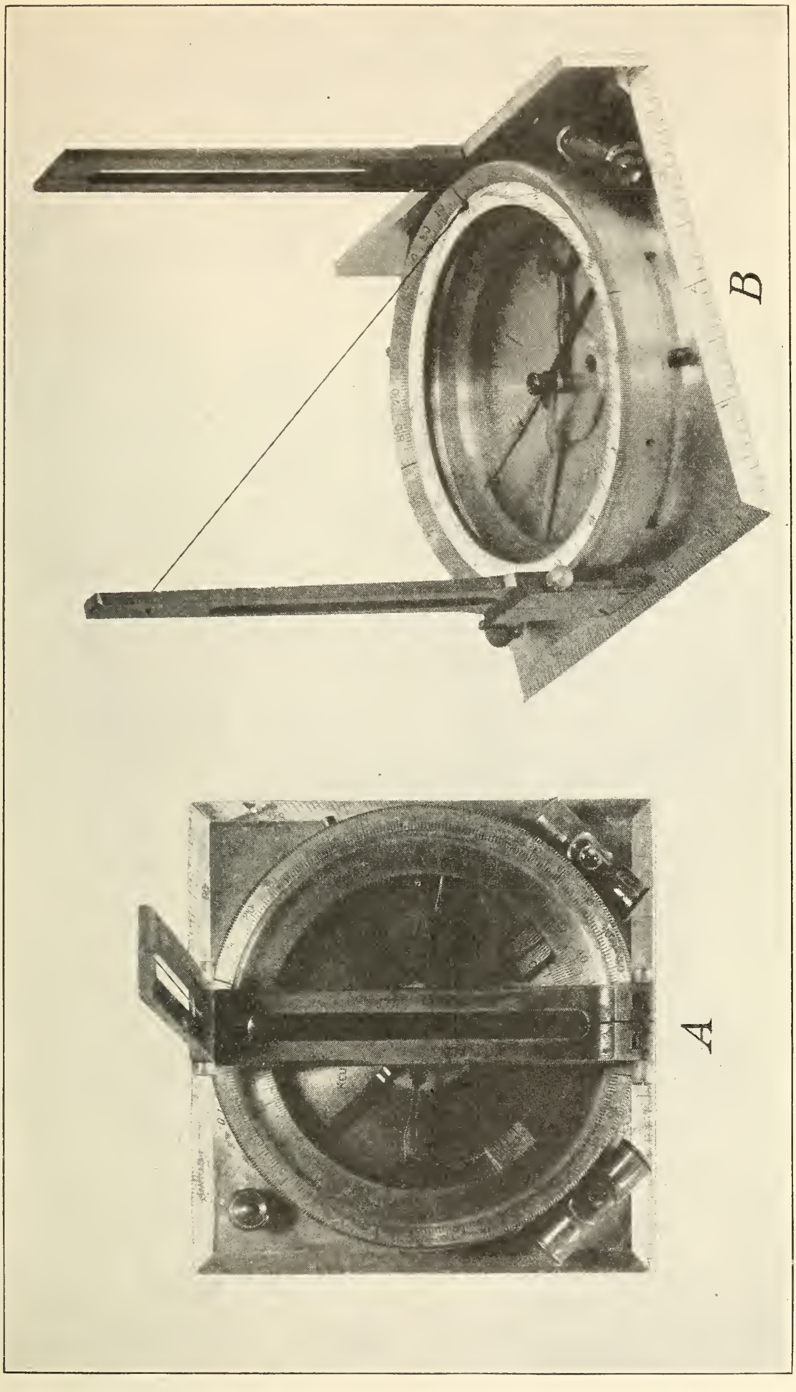

FIGURE 7.—*A*, Forester's or geologist's compass; *B*, sundial compass.

be used also in nonmagnetic areas, but primarily it is for use in areas having magnetic attraction.

Obviously it is impossible to calibrate this instrument so that it can be used in all places or even during all months in the same place. Thus each compass must be specially standardized from time to time in the particular area where it is used. First, a true north-and-south line must be established. If the attraction is only local, this can be done with a magnetic compass in a nonmagnetic part of the area. Generally a line of known direction will be available even in a magnetic country. But if one is not, and it is impossible to find a nonmagnetic part of the area, arrangements will need to be made for the services of an engineer equipped to establish such a line by astronomical observations. After the compass has been oriented in a true north-and-south line, beginning early in the morning and continuing throughout the day, readings must be taken on the sundial at intervals of 5 minutes. Obviously these readings can be made only during a clear, cloudless day. The surveyor must be equipped with an accurate watch which should be checked against the true standard time as frequently as possible, preferably daily. A watch varying more than a few seconds in 24 hours is unsatisfactory for this purpose. After the readings have been obtained, they may be plotted on regular coordinate paper, using the time by the watch as one axis and that by the sundial as the other. A curve showing the relationship between the two can then be drawn by connecting the points. The curve will have small but irregular and significant variations from a straight line of 45°. This curve will need to be carried by the surveyor in the field.

In order to establish a direction in the field with a sundial compass, the instrument is set up firmly with a Jacob's staff and leveled. A point on the curve 1 or 2 minutes in advance of the time by the watch is chosen and the equivalent time on the sundial noted from the curve. The compass is moved so that the instant the chosen time on the watch is reached, the equivalent time is indicated on the sundial. For example, suppose the time by the watch is 10:38 and by consulting the curve, it is noted that when the time by the watch is 10:40 that by the sundial is 11:18. The compass is turned so that the shadow of the string falls on 11:18 of the sundial precisely when the watch reads 10:40. The compass is now oriented in a true north-and-south line. By releasing the needle and noting the variation, the direction of lines in respect to true north can be obtained. It should be pointed out that orientation by this method is more dependable in the middle of the day than in early morning or late afternoon when the shadows move more rapidly.

SOIL-SAMPLING TOOLS

The soil surveyor's most important tool is the humble spade (fig. 8, *A*) supplemented by the pick and the soil auger. For careful examination of soil profiles, as in the initial work of preparing a mapping legend, the spade is used almost entirely. For the frequent and more hasty examinations of the soil in mapping, it is generally superior to the auger but not always so. For example, the chief differentiating characteristic between two soil types may be simply the distance to an underlying stratum of clay at considerable depth

or to variations in the color of the substratum, and in such instances the soil auger may be better than the spade, from the point of view of time and convenience. Where structural differences in soil are important, as they frequently are, the soil auger is of little use. In dry, stony soil, neither can be used very rapidly, but the soil auger is out of the question, and the pick becomes a most useful tool. Whenever practical, the spade should be given preference over the soil auger, as a better and more complete examination of the soil is possible. In areas where the soil auger is used to considerable extent, the soil types must in all instances be examined with a spade in order to establish completely their internal morphology.

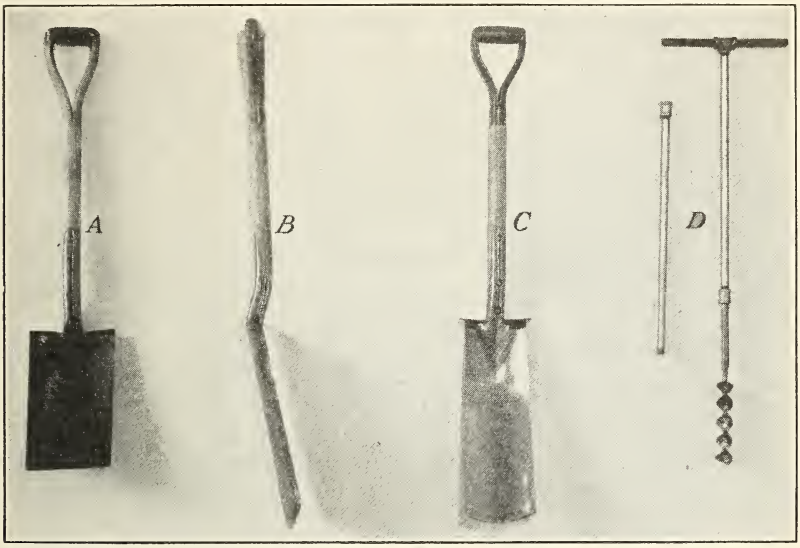

FIGURE 8.—Soil-sampling tools: *A*, square-pointed spade, especially useful in collecting samples; *B*, side view and *C*, front view of post-hole spade, the most generally useful sampling tool; and *D*, soil auger with extension.

The best spade for ordinary use in the field is a modified post-hole spade shown in figure 8, *B* and *C*. The common tiling spade tapers somewhat too much at the end and the metal is generally too thin. The sharp corner of the post-hole spade should be removed for best results. For use in collecting samples, especially after the preliminary excavation has been made, the flat square-pointed spade is most convenient. In desert sections where deep holes are required and soils are gravelly, stony, or more or less cemented, the long-handled irrigator's shovel is more useful than the ordinary spade. It may be necessary to supplement this with a heavy crowbar.

The soil auger is shown in figure 8, *D*. This tool consists essentially of a 1½-inch wood auger, from which the cutting side flanges and tip have been removed, welded to a steel rod or iron pipe with a crosspiece at the top for a handle. For ordinary use, the auger is from 40 to 48 inches long with provision for adding extra length for deep boring. Where an auger must be used a great deal, it is

usually convenient to have one of the length most commonly used made solidly throughout and another extension auger for the deeper borings. For use with soils of exceptionally high clay content, a bit 1 inch in diameter may be more convenient than the larger one. It is a great convenience to have the distances in inches from the tip of the auger marked on the shaft.

The appearance of the soil is frequently decidedly changed when removed with the soil auger as compared to that which it has in place. The beginner must use both the spade and the auger at the same spot, in order to note these differences and not be misled by them. Although the auger is very simple in design and somewhat crude in appearance, considerable skill is required for its effective use in making dependable observations of the soil profile.

Suitable excavations frequently cannot be made, especially in hard, dry, stony, or gravelly soils, without the use of a pick which must always be part of the soil surveyor's equipment. In most instances a small trench pick will serve satisfactorily, but frequently a heavier one or a heavy chisel-pointed bar will be necessary. A geologist's hammer also is a useful implement, especially for the examination of rocks within or beneath the soil.

Peat sampler.—For the examination of deep deposits of peat a special device is used. There are several such devices, but the one in most common use in the United States is the Davis peat sampler or some modification of it as shown in figure 9. The instrument consists of 10 or more sections of steel rods, each 2 feet long, and a cylinder of brass or duraluminum approximately 14 inches long with an inside diameter of three-fourths of an inch. The cylinder is provided with a plunger, cone-shaped at the lower end, and with a spring catch near the upper end. When pressed into the ground, until the desired depth has been reached for taking a sample, the spring catch allows withdrawal of the plunger from its enclosing cylinder. Locked in that position, the instrument may be filled with a solid core of the respective organic material of that layer by a further downward movement. The cylinder protects the sample completely from any contamination and does not destroy its structure when the instrument is removed. Beginning at the surface downward, samples of peat are taken consecutively at intervals of 6 inches or 1 foot. The lengths of steel rods used allow an easy estimation of the depth reached below the surface from which the respective peat samples are obtained.

FIELD TESTING APPARATUS

There are few reliable field tests of soils that serve a useful purpose in the soil survey. One of the most useful and most important is the simple test for carbonates with dilute hydrochloric acid. The presence of carbonates in the soil or the parent material must be detected, since it has considerable bearing on the characteristics of the soils important in soil classification, as well as on the capabilities of the soils for plant growth. When testing dry soil with acid the emission of a few air bubbles must not be confused with actual effervescence of carbon dioxide. When testing rocks and especially rock fragments in the soil, these must be broken and the acid applied to the fresh break. Hard dolomitic limestones frequently do not effer-

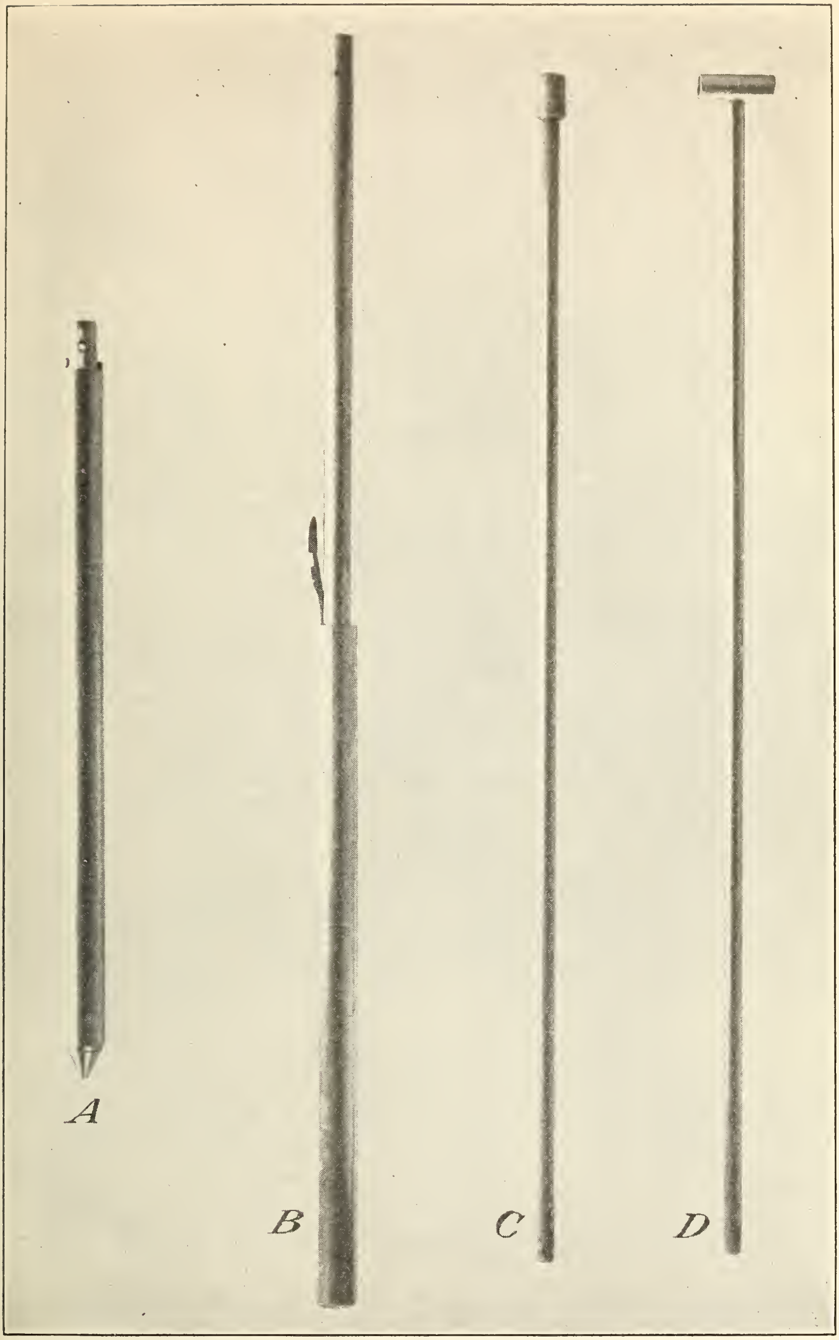

FIGURE 9.—Peat sampler: *A*, the head closed, ready for pushing into the peat; *B*, the head extended, as just prior to taking a sample; *C*, one 2-foot extension rod, and *D*, the top extension rod.

vesce when treated with cold dilute hydrochloric acid. Hydrogen peroxide (1½ to 3 percent) may be used satisfactorily in testing for manganese dioxide by noting the effervescence.

Several tests, based on the use of one or more colorimetric indicators, are available for estimating soil reaction in the field. In general such indicators appear more reliable with soils under about pH 7.5 than with those more alkaline. Testing outfits requiring a minimum of equipment are to be preferred, as it is frequently difficult to obtain distilled water in the field, which is of suitable quality for rinsing containers. Tests using wax paper for holding the soil to be tested have the great advantage of not requiring any washing of equipment in the field. Depending on the particular soil region and the problems to be met, the party chief will decide what reaction test to use, if any. It is usually advisable to make sufficient tests of soil reaction for a determination of the general hydrogen-ion limits of the horizons of the soil types shown on the map, especially in areas lying within the general region of the Pedalfers. On the basis of the experience of people making tests on similar soils of the general region in which the survey is located, a suitable test will be chosen. As conditions vary somewhat from area to area and as improvements in the testing outfits offered for sale are constantly being made, no definite recommendations will be given here.

Determinations of hydrogen-ion concentration are made in the laboratories of the Bureau of Chemistry and Soils on the official samples collected for correlation, by the use of the hydrogen or glass electrode. If, for any reason, a doubt exists regarding the accuracy of the field method in use, duplicate samples of several different soils should be sent to the laboratory in Washington for checking, or to the laboratory of any cooperating agency equipped to do accurate work. Small differences in reaction of Solonchak and Solonetz soils, by tests used in the field with indicators, ordinarily are not significant. The equipment required for determining the salt content of such soils will be discussed later.

Field tests for available plant nutrients, such as phosphorus, have not been developed to the extent that definite recommendations can be made now. The problem of devising chemical tests that may be used in the field is being actively investigated, and soil surveyors probably may look forward to having such tests sometime in the future, in order to give their descriptions of soil types more specificity. Several tests are now on the market, but it appears certain that no one test will be suited to all soils, and the range of suitability of the tests now available remains to be determined. In many instances, tests of this character have been developed by the State experiment stations with which the Department of Agriculture cooperates in making soil surveys. If it appears to the chief of the survey party that dependable tests for available plant nutrients are adapted to his area, he should make arrangements for their use to the extent that valuable information of use in describing the soils can be obtained.

PREPARATION OF THE BASE MAP

Soil boundaries and other symbols indicating soil conditions must be plotted upon a suitable base map. Where such a map is already available the soil data can be plotted on it directly; otherwise the soil surveyor must prepare one. It is important that the base maps show the local detail accurately, and local points of reference on the ordinary detailed soil maps, published on a scale of 1 inch to 1 mile, should not be over 125 feet in error. A correspondingly lower percentage of error is required for maps of a larger scale. In addition to accuracy of local detail, it is desirable that maps correspond to recognized cartographic standards for maps of the same scale, in a geodetic sense.

In the first place, the chief of party must be certain that he has all available useful cartographic data. Even if such data are insufficient in themselves, they may be of great value in preparing a base map and especially in adjusting the map for publication.

USE OF EXISTING BASE MAPS

As soon as an area is taken up for survey the chief of party will assemble and evaluate the data available. Useful maps which are not on a suitable scale can be reduced or enlarged to the appropriate mapping scale by photography.

TOPOGRAPHIC MAPS

The most important base maps used directly in soil surveying are the topographic maps made and published by the United States Geological Survey. Collectively, these are designed to constitute a topographic atlas of the United States. For this purpose the country is divided into quadrangles, bounded by parallels of latitude and meridians of longitude. Each sheet of the atlas is a map of some quadrangle. The quadrangle maps are published on different scales, depending on the needs and development in the various parts of the country. The differences in scale involve corresponding differences in the size of areas represented. The 1° quadrangle (scale 1:250,000) is the largest unit, and the 15′ quadrangle (scale 1:62,500) is the average unit. Standard contour intervals are 1, 5, 10, 20, 25, 50, 100, and 200 feet. The particular interval used depends partly on the scale of the map and partly on the character of the relief to be represented.

Topographic quadrangles on the scale of 1:62,500 (slightly larger than 1 inch equals 1 mile) and of fairly recent issue are usually suitable for base maps in soil surveying. Transfer impressions from the original engraved plates may be used in the reproduction of the soil map with considerable saving in cost of both drafting and reproduction, provided the soil map can be published on the same scale as that of the topographic sheet. Maps of a larger scale than 1:62,500 can be used to advantage in the field mapping but without any saving in the drafting or reproduction of the soil map. Whenever the scale of the published soil map must be different from that of the topographic quadrangles, the contours cannot be shown on the soil map without great additional expense.

When topographic quadrangles are used as base maps they must be checked carefully for errors, particularly as to cultural fea-

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tures, and brought up to date. Especially where the topographic sheets are old, revision may become more time consuming than a resurvey. The chief of party must appraise the value of any existing maps by a careful check in the field. Occasionally the base itself can be used, although the contours are not sufficiently accurate for publication on the soil map.

REVISION OF TOPOGRAPHIC QUADRANGLES

The revision of topographic quadrangles will involve as much new surveying as may be needed to correct errors and to add any symbols for new cultural features to the map. These must be tied to the unchanged cultural features. With such additions, some changes in relief and drainage, as shown on the map, may be necessary. Where the cultural revision is extensive, correspondingly extensive changes in the other symbols probably will be required. Revisions should always be made with the same care and in the same manner as a new survey.

All corrections and changes should be assembled on an extra sheet devoted specifically to this purpose. Preferably traverses are made directly on this sheet, but if this is not convenient they must be transferred to it accurately. This cannot be done with sufficient precision by freehand. Corrections must be made with inks of colors contrasting to those used on the map. Changes in culture may be indicated with red, changes in drainage with green, and contours may be corrected with purple. Small changes which easily might be overlooked, such as the crossing off of a house, should be circled in red. Any doubtful points, which might lead to confusion in drafting the map, should be described by marginal notes.

A definite plan must be arranged for checking the map such that no feature is overlooked. Civil boundary lines, especially those of newly incorporated villages or urban subdivisions, need to be verified. Occasional errors in topography can be corrected by sketching, but extensive revisions should not be undertaken. If the contours can be accepted without much revision the corrections can be made before publication; otherwise it is better to omit the contours altogether. Changes in drainage usually require alterations in the contours. Each place name on the map must be verified; those fallen into disuse should be dropped and any new ones added. Frequently, for example, rural post offices have been discontinued, due to the introduction of rural free delivery.

Ordinarily the largest number of changes will be in the symbols for roads and houses. If a house shown on the topographic map has fallen into such a condition as to be uninhabitable without extensive repairs, it should be dropped from the map. Frequently large numbers of new houses must be added. Primary roads may have fallen into poor repair and need to be shown as secondary roads or omitted from the map entirely. Secondary roads may have been improved to the status of primary roads. These corrections are made easily on the correction sheet by inking over the old symbols in red.

The contours on the topographic map are useful in indicating the lay of the land, but the soil surveyor must guard against following them too closely with soil boundaries. Although soil boundaries frequently may be found to follow the contours closely, especially along the edge of entrenched stream bottoms, the broken edge of

terraces, and tops of sharply dissected plateaus, their position always must be determined by independent investigations. Soil boundaries should be shown in black waterproof ink, preferably as dotted lines.

REVISION WITH THE AID OF AERIAL PHOTOGRAPHS

The topographic map may be revised in respect to culture and drainage by the use of aerial photographs, a procedure that promises increasing usefulness as the quality of the photographs and the methods of using them are improved further. The use of such photographs must be confined to the revision of maps having good ground control and the topographic details well adjusted. If the map which needs revision has insufficient control, aerial photographs cannot be used with accuracy until further control has been supplied by additional field work and the map readjusted. Such a procedure is usually not warranted as compared to a complete resurvey.

Aerial photographs taken with a single-lens camera are especially useful for the revision of maps of cities, towns, or other closely built areas. Those taken with a multiple-lens camera are much less satisfactory, since the wing-print parts represent exposures taken at an angle and show objects in such increased perspective that high buildings, and even ordinary dwellings, obscure the streets and render the ground plan of buildings indefinite.

CHARTS OF THE COAST AND GEODETIC SURVEY

By photographing to the same scale as that employed in the soil survey, the charts of the United States Coast and Geodetic Survey may be very useful, especially for the location of shore lines. These may be transferred to the field sheets under construction. The data from the charts must be checked carefully, to insure their correct adjustment, and tied to the traverses on the new map. As with the topographic sheets, these charts must be revised in respect to any possible changes since their publication.

GOVERNMENT LAND OFFICE PLATS

The plats of the Government Land Office have been drawn from survey notes, and although they cannot be used as base maps they are very useful in checking plane-table and compass traverses. The distance between section corners and the intersection of section lines with important streams and other prominent physical features usually is given accurately. The accuracy of the data on these plats varies greatly, but in areas where they are available the chief of party always should have them at his disposal and use them to the extent their accuracy merits. Wherever practicable, section corners and meander points should be located and shown on the field sheets by appropriate symbols. In many areas having few roads, these section corners furnish the most important control for adjusting the map.

USE OF AERIAL PHOTOGRAPHS

Considered from the point of view of local detail alone, the best base upon which to place soil-survey data is a vertical single-lens aerial photograph of convenient scale and good quality. In open country it is possible to keep close location with such a photograph

without reference to ground measurements or orientation by compass. This can be accomplished simply by reference to features of the landscape that are sufficiently conspicuous to appear on the photograph. In most open country, trees, buildings, fences, and streams are numerous enough to enable the surveyor to determine his location and to delineate soil boundaries and other features in reference to the visible objects. The disadvantage of aerial photographs lies chiefly in their variation in scale, both within the individual photograph and between photographs, and in the difficulty of reducing and assembling the material into a small-scale map.

Detailed mapping is done either upon the aerial photographs or upon transparent material, such as thin sheets of cellulose acetate, fastened over the aerial photographs. The photographs, together with the transparent overlays, may be carried into the field in a Tatum holder, on a light traverse board, or in some similar manner. In a locality where there is considerable timber, some surveyors prefer to use a light traverse board, fitted with a small compass, and a Jacob's staff, for convenience of orientation.

By using the transparent material over the aerial photographs, the features and the detail of the photographs can be seen readily, but as the sketching is done on the covering material, the map data, such as roads, houses, and soil boundaries, are kept separate from the photographic detail, leaving the pictures unharmed for future reference. Two types of transparent material are used. One has a lightly etched finish on one side that will take pencil readily and upon which erasure is easy, but such a sheet is not quite so clearly transparent as the unetched material. The perfectly clear, or unetched, material will not take pencil lines but requires ink. The use of ink in the field has certain disadvantages, but it has been found practicable to use certain kinds of ink in fountain pens, and some work has been done in this way. The photograph itself is perfectly visible through this type of material, the ink dries quickly, and the copy is clear and makes good photographic reductions or optical images when the data are assembled into a final map.

In practice it is found that much of the photographic detail may be sketched on the overlay sheet or photograph before going into the field. Roads, visible section lines, field fences, streams, and even some perfectly obvious soil boundaries can be traced tentatively. Pictures of hilly wooded country can be studied stereoscopically in the office, and in places drainage can be drawn best under the stereoscope. Such office work also allows the planning of traverses, in order that the surveyor may see and examine the places that are obscure on the picture, with a saving of time in the field.

Each overlay sheet covers only a relatively small area, depending on the scale of the photographs, but the sheets are joined readily because they are transparent. Well-made photographs, although they may vary slightly in scale, are usually sufficiently uniform in this respect to allow proper joining.

Although the preparation of a soil map from the overlay sheets or photographs is a problem for the drafting room rather than the field, it is frequently done by the men who did the field work, or under their

direction. There are two general methods of handling this problem, which have been used successfully. Both involve the preparation of a controlled base map and the fitting of images or photographic reproductions of the overlay sheets, or the aerial photographs, into it. The work of assembling and plotting the control data is done by experienced cartographers. The preparation of a suitable base map, however, may involve the running of traverses in the field to supplement other control data and furnish a sufficient number of well-located lines and points for proper orientation and location of the small field sheets.

Following the preparation of the base map, the assembly may be done either by photography or by means of a projectoscope. In the photographic method, each of the small maps on the field sheets is reduced to its proper scale by fitting its image into its proper place in the base map by means of an autofocus reducer. The image, when once adjusted, is thrown upon photographic paper and the photograph made and developed. It is then necessary to trace this in its proper place in the base map.

The other method involves throwing an image of the field sheet into its proper place in the base map by means of a projectoscope and tracing the lines of the image directly.

Experience indicates that the scale of the photographs may range from 3 to 6 inches to the mile for ordinary soil-survey work. On such a scale all such detail as can be reproduced on a published map of 1 inch to the mile may be drawn. A scale of 2 inches to the mile has been found convenient for the assembly, or base map. Further reduction to publication scale can then be accomplished by photography.

PLANE-TABLE TRAVERSE

It frequently happens that no accurate base map is available for the area that is to be covered by a soil survey. It is then necessary for the soil surveyors to construct a base map by plane-table traverse. The making of such a traverse consists of plotting on paper the direction and distance of certain essential features of the landscape in such a way that the objects shown occur on the map in the same relative positions they occupy on the surface of the land. By adding names and symbols to the various objects shown, a clear impression is conveyed as to the character of the country. Although the system used is simple and the operations performed easily, it is only by constant care and strict adherence to the exacting rules of performance that a base map of accurate character is produced. The secret of good plane-table work is almost entirely a matter of care and neatness. The soil surveyor usually becomes sufficiently proficient to carry on coincidentally both construction of the base map and soil mapping, after the primary traverse has been completed.

The equipment required for a plane-table traverse includes a special type speedometer to be attached to the front wheel of an automobile for measuring distances, a plane-table board with attached compass, tripod, alidade, sharp-pointed fine sewing needles, hard-lead pencils,

erasers, drawing paper, notebook, and cover paper (to protect the unfinished map). The special equipment has already been described and illustrated.

First, the main roads are traversed with the plane table. The other prominent natural or cultural features adjacent to them are located at the same time, including especially any control points, such as triangulation stations or section corners. This grid, or skeleton, is called the primary traverse and should be completed and closed with acceptable accuracy before any detail is placed on the map from secondary traverses within the grid. Almost any point may be chosen for a starting point, but it is best to select a well-located point near the center of the sheet. An intersection of two roads leading to the four sides of the sheet would be ideal.

After the plane table has been set up and leveled, the compass needle is released and the board turned until the needle is coincident with the north-south line in the compass box. Since needles may be slightly bent, the check should always be made with the north point. This orients the paper. A sharp-pointed needle is pressed into the paper in the approximate position which the plane table occupies in respect to the area to be shown on the sheet. In order to represent on the map a line between the plane table and some distant point, the margin of the alidade is placed against the needle and rotated until the two sights are directly in line with the distant point. While the alidade is held firmly in place, a fine line is drawn on the paper. Distances between the two points along the road are measured with the speedometer. Additional "shots" may be made at buildings and other prominent points.

When the work at the initial station is completed, the compass needle is lifted from its pivot, and the instruments are placed in the autotruck. The surveyor then proceeds in the direction of his shot, carefully noting the speedometer reading at the start, as streams are crossed, as other features are passed, and especially as the point on the road at which he sighted is reached. He then continues along the road until it bends, until he has reached a distance on the ground somewhat less than one-half the length of the compass needle on the map, or until he reaches a road intersection or some other place where a new set-up must be made.

The plane table is set up and oriented at this new station. The distance from the first station to the end of the first sight is laid out with the scale on the alidade and the needle pressed into the paper at that point. By placing the alidade against the needle and sighting back upon that point, a line can be drawn to the present station. The distance from the turning point to the present station is laid out with the scale and the needle pressed into the paper at the new position of the plane table, after which a new forward sight is taken on the road and any necessary shots are made along intersecting roads or at other points. If the field work is done on a scale of 2 inches to 1 mile, as in most soil mapping, measurements can be plotted within about 15 feet.

It will be noted from the above that the plane table is set up at every other station or at every other bend in the road if intermediate set-ups are unnecessary. This is called the "system of turning points." Great care must be taken that there is no steel culvert or

similar object to cause magnetic interference. If in doubt, the plane table should be set up at the intermediate point and the previous forward shot checked by a back sight. Where there is magnetic attraction which cannot be avoided, traverses can be made for a short distance by orienting the board by back sights rather than with the compass. This requires a set-up at every station. The alidade is placed firmly on the paper parallel to the last forward shot and the board turned until the previous station is sighted. The map is now oriented and, after determining the present position of the plane table on the map by plotting the distance, a new forward sight can be taken. When the board is oriented by the compass the error is compensating, but when oriented by back sights it is accumulative. The equipment already described and used in ordinary soil surveying is not sufficiently precise for use without the compass, except for short distances.

At the same time the plane table is set up for making sights along the line of traverse, houses and other features near the road may be plotted from the measured distances and by sighting with the alidade. Frequent stops to examine soils and to make side traverses will be necessary while making secondary traverses but should be avoided while the primary traverse is in progress.

Houses and other objects distant from the road may be located with sufficient accuracy by the intersection of sights made from two or three stations. The distance between these stations must be sufficiently great that the inside angle is about 90°. This technique is referred to as "graphic triangulation." It is much simpler than the triangulation executed with more precise instruments. Trees and other objects along a stream in open country may be located temporarily in this manner as a guide to sketching the stream channels. Similarly, other points may be located as an aid to sketching soil boundaries and for locating rock-outcrop symbols and similar features. It is also frequently desirable to locate, by intersection, trees, hills, and other distant landmarks as an aid to checking subsequent foot traverses through areas distant from roads.

No attempt should be made to correct lines and sights to true north, although the local variation of the compass should be ascertained from local engineers or published data and indicated on the plane-table sheet. In regions where roads and other lines extend at wide variance from magnetic north it is often found to be desirable to attach the compass at such an angle to the side of the table board that there will be sufficient compensation to cause lines of roads to extend approximately parallel to the edge of the board and thereby allow convenient joining of the various sheets. Extreme care should be taken to maintain the compass in exactly the same position on the board from the time a sheet is begun until it is completed.

All traverse work on a sheet should be based on one starting point, preferably near the center. Ordinarily, more accurate traverses are made by starting each sheet from a separate starting point near the center than by traversing to the edge of one sheet and continuing from the margin toward the interior of another sheet. Some distinct feature, such as a cross road or a tree, near the edge of the sheet, should be selected as an end point for the traverse. This point must be well marked so it will be easily recognized when later traverse

work reaches it on the adjoining sheet. It is desirable, and frequently possible, to traverse roads common to adjoining sheets. It is essential that such common roads be located on each sheet by individual traverses in order that the sheets may be properly joined and adjusted.

Secondary traverses are made, after the primary traverse has been completed, between the principal traverse lines for completing the base map and soil map. Except in heavily wooded or brushy country the plane table can be used conveniently. The technique is similar to that employed for the primary traverse except that much of the measuring must be done by pacing. Foot traverses must be tied to control points such as section corners or other points located by the primary traverse at frequent intervals. In many instances, where secondary traverses are made over hilly or broken terrain, it may not be possible to pace accurately and the surveyor must locate himself by other means.[8]

The plane table can be set up, oriented with the compass, and sights taken at two or more previously located points. The new station is located at the intersection of the lines drawn from these sights. Stations should be selected such that the lines are as nearly at right angles to one another as possible. Every effort should be made to check each location made in this way by sighting at a third point. When mapping in very rough country it is commonly necessary to place special flags in conspicuous places for use as control stations. In sectionized areas it may be possible to identify section corners, which may be located on the map by construction from the grid of the primary traverse, supplemented by data from accurate Land Office plats, and these points used for checking secondary traverses or as control stations when locating new stations by graphic triangulation.

If it is necessary to occupy a point where the plane table cannot be oriented by the compass, due to local magnetic attraction, and to which measurement cannot be made, the location can be determined as follows: A forward sight is taken from a known point toward the new position. (This may have been done at any time prior to the final location.) The plane table is then set up at the new station and oriented by sighting back at the previous station. A sight is taken at some other known station, and the intersection of the two lines gives the location of the new station. It is better, however, to locate such a point by sights taken from both known stations, and if the plane table cannot be set up in the exact spot which was sighted it may be set up along either line of sight, oriented by a back sight, and the proper allowance made for the distance between the located point and the new station.

CONTROL FACTOR IN MAP ACCURACY

The field sheets, when completed and sent to the drafting office, are joined and adjusted to control points by cartographers so that the completed map is geographically correct, indicates the proper position and shape of the area on the earth's surface, and shows the relative direction from and distances between all points in the

[8] For a more detailed discussion see Beaman (*1*).

area. The control that is necessary for the accuracy of the map embraces first the primary control on which the survey for the map must rest. Soil surveyors are not equipped to execute this primary control. There are few areas in the United States which cannot be tied, by distances and direction, with points already established and obtainable from the records of the Coast and Geodetic Survey, the Geological Survey, the Lake Survey, the Corps of Engineers of the Army, or the Mississippi River Commission. These records must be utilized to the fullest extent, and information drawn from them is furnished the chief of party who should not fail, under any circumstances, to be certain that his primary traverses are tied to these points which have been located accurately by other governmental agencies. The greater the number tied to the soil map, the better will be the result of final adjustment. It is essential that control points be tied to the plane-table traverse by actual traverse or, when the control point is conspicuous, by intersection of at least three sights from the primary traverse.

This primary control is supplemented by further control obtained by means of the mapping operations, of plane-table traverse, and plane-table triangulation. As a result the area under survey is so gridironed or covered by lines and locations that no essential map feature is so far from a traversed line or located point that it cannot be seen and delineated satisfactorily.

It is also absolutely necessary that range, township, and section lines, railway stations, mileposts, and similar features be indicated for purposes of making correct adjustments of the traversed roads and other features on the map.

It is helpful to the map adjusters in the drafting office to have the directions of the main traverse shown by small arrows pointing in the direction the traverse has proceeded. Curved arrows shown in red ink are used to indicate the connection required for points of closure, where a closure error occurs. Where overlapping or crossing of plotted lines occurs at the point of closure, the closure error is indicated by a looped line in red ink.

Careful judgment will be required to cover the entire map adequately to the end that there is no part of the area which has not been properly investigated and that too much time is not devoted to parts that happen to be easy of access and too little given to other parts that happen to be difficult of access.

ACCURACY OF OBSERVATIONS AND OF PLOTTING

Although it is a waste of effort and expense to execute surveys on the ground with an accuracy greater than that which can be plotted on the scale of the field sheets, there will be a failure to get full value from effort and expense already incurred if the results of the field work are plotted with an accuracy less than that of the observations themselves. The soil surveyor must think, therefore, of ground features in terms of scaled map distances and dimensions and correctly plot his measurements under favorable plotting conditions of light and magnification and without parallax. Refinement in paper work is fully as important as care in field measurements.

The map should be as consistently accurate in all its parts as is practicable. If two or more field men are responsible for the map-

ping of independent areas on the same or adjoining plane-table sheets, they should compare their maps, not only at their common borders, but throughout, in order that they may reconcile any differing interpretations of the country or of the instructions under which they are working. One of the principal duties of the chief of party is to harmonize the work and bring about uniformity in all phases of the mapping.

The date of survey is given on each published map, and the accuracy of the cultural representation must be considered as of that date. Although reasonable effort should be made to obtain information regarding all important changes in culture, even though the area affected has been mapped previously in the survey operations, no proposed road, house, or other feature that has not been constructed and on the ground should be shown. Such features as roads and railroads under construction may be plotted so far as actually graded, but unless they are known to be in use when the map is inked they should be shown on the final drawing in red, as features not to be included on the published map.

The most obvious source of inaccuracy in a map is error. A map error may be caused by an incorrect measurement or an inaccurate plotting of a distance, by the incorrect measurement of an angle, or by an error in a field computation. An error in sketching may also result from the misinterpretation of the shape of a distant or otherwise veiled feature seen in perspective. If an error is followed by another error that is made in the opposite direction the errors are termed compensating, as one tends to offset the other. Where compensating errors are nearly equal, the results under certain conditions, as in compass traverse work, may have a false appearance of accuracy as the traverse will close and yet be in error in two or more places. In general small compensating errors may be disregarded, but where such errors are large they are a source of difficulty until found and corrected. In this connection it must be stressed again that accuracy of local detail is especially important on detailed soil maps.

In order to guard against error, all traverse lines so far as practicable should be run in circuits closing on themselves or run from one located point to another; and, barring compensating errors, a line that closes or checks is assumed to be correctly plotted. Long traverse circuits should be avoided if possible. The errors to be guarded against especially are those which may result from isolated measurements, unrelated to other features, and the possible accumulation of errors in unchecked lines. There is almost always a failure of the traverse to close exactly, even if no mistakes have been made in measuring, sighting, and plotting. This is due to natural causes and occurs in the most exacting surveys with the most precise instruments. The normal result will be, therefore, a lack of exact joining of the completed circuit. Such errors are known as "closure errors."

These closure errors must never be adjusted in the field but must be shown as such and the adjustment left to the drafting office. This closure error must not be greater than the allowable error for the survey. If the error is large and not revealed by replotting the field notes, the traverse must be run again. It is very important that closure errors be shown distinctly, to enable the cartographer to adjust the lines of traverse and other features into their proper

places. These should be shown in red ink, never in towns, but at points where they will not be confused with symbols for features. For this reason traverses should not be started in congested areas. The location, by intersection, of prominent features of the landscape, such as trees, towers, or hills, at some distance from the line of traverse can be sighted frequently as a check for indicating any considerable errors that may occur in plotting and sighting. The careful traverse man constantly provides checks for his work in this way.

The plane-table methods employed in mapping enable the surveyor to detect and correct most errors in the measurement of distances and in plotting, because such errors usually produce erroneous mapping that will not fit other data that are correctly placed from other control. The check on the accuracy of the map that is afforded by its constant comparison with the features themselves as they are being mapped is a test that is repeatedly applied by the experienced surveyor.

Inaccuracies in a map may also result from omissions. A house or a name may be omitted because of simple neglect or because of a lack of sufficient supplemental control. In the first instance there has been lack of care, and in the second the standard of accuracy is deficient. The omission of essential features from a map because they were not seen or recognized as such during the progress of the field work can be guarded against only by close observation combined with a control that is fine enough to close all unseen gaps. A feature that has been plotted in the field may be lost before it is inked because of faint penciling, or it may be lost during the inking through inadvertent erasure. Faithful proofreading is the safeguard against such omissions.

In a sectionized country where Land Office plats are available, it is desirable to check the plane-table traverse with these and indicate the section and township corners on the plane-table map. The location of section lines should not be plotted on the plane-table map from Land Office surveys alone, as the older of these plats are sometimes in error. In areas, however, where these plats have been checked and found to be accurate, the measurements serve as a useful check, especially in those parts of the area having no roads. All measurements should be made with the speedometer, and the section corners should be indicated, so that the map can be adjusted later to the Land Office plats and other control. After the primary traverse has been completed and as many section corners located as possible, the section lines can be drawn in, using the Land Office plats, where accurate, for section lines distant from the traverse lines. Attempts of the field man to adjust his plane-table traverse to land lines and corners in the field according to distances indicated by some other survey frequently result in confusion and difficulty to the cartographer, who finally connects the sheets and adjusts the map. If any other data or measurements of any kind other than his own are used, distinct notations should be made, giving the authority for the data.

TRAVERSE NOTES

Measurements of distance between traverse points, and features between stations, such as turning points, streams, crossroads, houses,

and soil boundaries, should be recorded in a suitable notebook. A convenient method of recording readings is to begin at the bottom of the notebook page and proceed upward as the work progresses. Readings taken at houses, streams, and other points can be indicated by a symbol at the side. By the side of the speedometer reading, the exact distance can be set down. These notes must be preserved carefully for future reference until the work is completed. A frequent check of total distance along the traverse, as shown by the speedometer, with the sum of the plotted distances, serves to indicate any possible errors in plotting. In this way errors in plotting can be apprehended before the traverse has progressed to the point where correction would be difficult.

COMPASS TRAVERSE

The compass traverse in certain instances may be used as a substitute for the plane-table traverse, especially for secondary traverses in heavily wooded areas. It should be used only under circumstances which make use of the plane table impossible or impracticable. For example, it is not possible to carry a plane table through dense woods or brush, and in places where there is local magnetic attraction it is sometimes more convenient to use the sundial compass than other more elaborate devices. The compass requires more time than the plane table, since each reading of the compass must be plotted on the map by use of a protractor.

Under ordinary circumstances in wooded country it is best to follow a straight line with the compass and avoid the need for plotting frequent changes in direction. This is especially true in sectionized country where the surveyor can follow land lines and where he has an opportunity to locate section corners as a partial means of control. Of course, if the walking through the brush is unusually difficult, time may be saved by plotting the traverse on a footpath or trail, but ordinarily these roads and trails are so crooked that their ease of travel as compared to that of the brush does not compensate for the time required in plotting their meanderings. A complete record of the compass readings and of the number of paces traveled must be preserved carefully for any necessary recalculations, should errors develop. The compass readings should always be noted as so many degrees east or west of true north or true south, whichever is more convenient.

No compass less precise than the ordinary geologist's or forester's compass already described should be used for traverse work in soil surveying. The common pocket, or box, compass, although convenient for picking one's way, is not suitable. With a good instrument and experience in the woods, a surveyor can run satisfactory lines for distances that are not too great. Especially where measurements are made by pacing, frequent checks on section corners or control points established by the primary traverse are essential.

PACING

Essentially all of the measurements of short distances plotted on the map are made by pacing. Each pace consists of two full strides, and the paces are counted by counting alternate strides. For this

counting a surveyor should always use a tally register and not attempt to carry the counts in his mind, for if he does he is absolutely certain to fail, either to count accurately or to note features of the landscape as he walks along. Each surveyor must determine very carefully the length of his natural stride. He must train himself always to keep this natural stride, regardless of the slope or ground cover. His paces must be exactly the same on the open highway as they are in the brush or in the fields. The pacing of each man must be standardized against a known distance and a table prepared showing the number of paces for each division on the mapping scale. For example, a surveyor who has 1,000 paces a mile will have 10 paces for each division on the ordinary alidade.

Although an experienced man becomes very skillful at pacing, errors may develop, due to fatigue or variations in his health and physique. Thus all traverses, with either plane table or compass, where measurements are made by pacing, must have frequent control even with good terrain. Even for the experienced surveyor, about 3 miles between control points is the outside limit for dependability. No traverse made by pacing for more than about one-half mile should be left without a tie to some control point or a check by graphic triangulation.

Pacing is unsatisfactory in extremely rough and broken country, and frequently saddle horses must be used. Occasionally saddle horses can be found that pace with considerable uniformity, but ordinarily locations must be established by graphic triangulation or intersection from section corners or other control points.

SYMBOLS USED

The features that must be shown on the soil maps may be grouped into four general classes: (1) Works and structures, including such works of man as roads, railroads, houses, churches, and wharves; (2) boundaries, marks, and monuments; (3) drainage, including streams, lakes, seas, ponds, and springs; and (4) soils. It is also sometimes advisable to show some of the more pronounced physiographic features or relief, such as mountains, cliffs, and escarpments and high-terrace lines. All features are shown by conventional symbols and lettering.

The work on the field sheets must be distinct, the lettering legible, and necessary corrections plainly indicated, if the draftsman is to understand them clearly and reproduce them faithfully. Strict attention to detail on the part of the field party will often save the delay of referring questions back to the field men, reduce errors in copying and adjusting, and generally facilitate the work in the office. Neatness and accuracy go together. A map that is not neat cannot possibly be accurate.

Nearly all works and structures are inked in black. A few exceptions are specified under the appropriate headings. Features added for information only and not to be published, or features for which publication may be in doubt, are inked in red. Boundaries, marks, and monuments also should be inked in red. A mixed blue ink is used for inking drainage features, and it must be thoroughly mixed and dark enough to insure strong photographic value. A

greenish-blue ink, made by mixing 2 parts of blue waterproof drawing ink with 1 part of yellow and a few drops of black, has proved satisfactory.

WORKS AND STRUCTURES

The following works and structures are shown on all maps, either by the standard symbols shown in plates 1 and 2 or by means of other conventions described in the text.

Aqueducts, water and oil pipes.
Bridges.
Buildings.
Canal locks.
Canals and ditches.
Cemeteries.
Coke ovens.
Dams.
Ferries.
Fords.
Furnaces and smelters.
Levees.
Lifesaving stations.
Lighthouses, etc.
Mines and quarries.
Oil and gas wells.
Power-transmission lines.
Railroads.
Reservoirs.
Roads.
Steamboat routes.
Trails.
Tunnels.
Wharves, etc.

Roads.—Roads are indicated according to the following distinctions:

(1) First-class or good public motor roads are shown by solid lines. These include those public roads that may be used for automobiles at medium speeds and for hauling, the greater part of the year, and include all Federal Government, State, county, or other public roads in such condition as to be available for such travel, all main or through roads in passable condition in sparsely settled sections, and all city streets and park drives open to the public.

(2) Second-class or poor public motor roads and all private roads, regardless of condition, are indicated by dashed lines. Secondary roads include those public roads which, through disuse or neglect, are either impassable for automobile travel and for hauling or cannot be traveled, except at low speeds, without risk to an automobile. Public roads that are passable for wagons but are not good for motor use are classed as poor motor roads.

It should be noted especially that public roads are shown by solid or dashed lines according to their condition, whereas private roads are shown by the dashed symbol irrespective of condition. Public roads are defined as those built or maintained by the Federal Government, a State, or a subdivision thereof. Private roads include all neighborhood roads in rural districts (except those of sufficient length and importance to be regarded as through routes, as defined above), all lanes and stub roads to farms, country houses, or institutions, cemetery drives and race tracks, and roads built or maintained by private or neighborhood funds.

Wagon roads winding through the timber and other unimproved roads used principally in farm operations ordinarily are not shown on the published map. Frequently, however, in sparsely settled country, such unimproved roads may offer to the public the only access to important places or to a large area of country, and in such instances they should be shown. Occasionally in unsettled areas pack trails, impassable to wagons or motorcars, may offer the only opening to a region and should appear on the final map. It is convenient to indicate all traverses on the field sheets, but great care must be taken not to ink roads or trails, which are not to appear on the published map.

The class of road should be shown on the field sheets with the appropriate symbol and not by figures. It is not convenient to indicate precisely where one class of road ends and another begins with figures, and the surveyor is apt to omit figures in a few places. In highly detailed surveys, especially where the soil map is used as a basis for detailed land classification, the class of primary roads must be subdivided according to the type of surfacing. All-weather roads may be shown with one line heavier than the other, and other primary roads by the conventional symbol. By appropriate modification different symbols may be used for graveled roads and for paved roads where this distinction is necessary.

Buildings in general.—The map must show accurately as to location and orientation all buildings of a permanent character, such as dwellings, public buildings, shops, factories, and other industrial establishments. Uninhabited dwellings, whether farmhouses or miners' and lumbermen's cabins, are to be shown only where they constitute important landmarks in sections of sparse culture. The conventional black square is used for all buildings except those exceeding the size of the symbol when their dimensions are plotted to scale. Houses should not be shown as contiguous to the roads unless the distance that separates them from the edge of the right of way is so small that it cannot be plotted on the scale of publication. Symbols for dwelling houses should be inked square and of uniform size on the field sheets. They are best made by outlining an open inked square with sharp corners, and afterward filling in with ink. If houses are shown too small, it becomes difficult to make the symbols square, and, unless these are inked square and sharp, their identification as symbols for houses becomes uncertain.

House blocks.—Detached houses in residential sections of cities, suburbs, and villages are to be shown separately wherever possible. If the scale does not allow the use of separate symbols for individual houses, groups are shown by a solid block, in accordance with the following specifications: Distances between houses are to be understood as from center to center, and the length of house blocks as between building lines and not from center to center of streets.

(1) For publication on a scale of 1:63,360 or 1:62,500: Houses, where nearly evenly distributed, are blocked if the distance between them is less than 100 feet; for example, in a 500-foot street block, six houses evenly distributed are blocked, but five houses or less are shown separately.

(2) For publication on a scale of 1:24,000 or 1:31,680: Houses are blocked where the distance between them is less than 50 feet; for

example, in a 500-foot street block, 11 houses evenly distributed are blocked, but 10 houses or less are shown separately.

Business and residential blocks are distinguished by the width of the block; residential blocks are made distinctly narrower than business blocks.

Churches and schoolhouses.—A church is distinguished by a cross and a schoolhouse by a pennant attached to the house symbol at right angles to the roadway. A building used as both a school and a church bears the school symbol. In the center of dense culture these distinctive symbols are omitted.

Railroads.—Railroads, whether operated by steam, electricity, gasoline, or other motive power, including all railroad lines listed in the Official Railway Guide, are shown by the broad-spaced symbol representing a railroad of any kind.

Electric trolley lines carrying passengers only and not issuing tickets with baggage-checking privileges are shown by the close-spaced symbol.

Double tracks, railroad yards, spur tracks, and switches are shown so far as the scale allows. Separate railroad lines in juxtaposition and parallel tracks belonging to the same road are differentiated by placing the cross ties as shown on the symbol chart.

Tramways are shown by the broad-spaced symbol. Aerial tramways are shown by a broken line, with names where there is space.

Railroads or electric trolley lines within a roadway are shown by fine cross lines having the same spacing as those on the corresponding line outside of the road. It will be necessary in such instances to use the double-line road symbol on the field sheet instead of the usual single line.

In railroad yards with parallel spur tracks, only as many tracks should be inked as can be engraved legibly on the publication scale, as too many tracks make difficult inking, illegible field sheets, and impracticable engraving. Where switches and sidings occur along side single tracks, both the main track and the side tracks are inked in finer lines than the main track elsewhere; and these fine lines are inked first and the extension of the main track inked afterward in a heavier line, in order to make clear copy.

Before a railroad is inked the penciled copy should be examined to determine its points of tangent and points of curve and then inked in such a way as to bring out the characteristic alinement. A railroad alinement is made up of tangents and curves; most curves are compound and many leave the tangent on an easement curve. Reversed curves usually have 200 feet or more of tangent between them. In traversing railroads these points should be kept in mind, and the resulting plot should show a line free from abrupt deflections that are not found on the ground. Railroad azimuths should be well checked, by fore- and back-sight methods when necessary.

Crossings at grade are shown by continuous railroad and road symbols and at grade separations by a break in the symbol for the lower one. A railroad crossing over a road is shown by a broken road symbol, and a road crossing over a railroad by a broken railroad symbol. (The words "overhead" or "underpass" should not be used.)

Railroad-station buildings.—A railroad-station building is shown like other buildings, except where its symbol is carried conventionally across the track to indicate the location of a train stop that is not otherwise clearly indicated by the position of the station name or by the culture. The conventional station symbol is not drawn across the track where there is no station building, and its use is generally confined to small villages or cities.

Bridges.—Symbols are used to show all road bridges across double-line streams and all road bridges across single-line streams in sparsely settled sections, wherever the existence of the bridge is especially vital to the use of the road. Bridge ends are not shown for viaducts over railroads, railroad yards, roads, or streams. Names of large viaducts are given, however.

Drawbridges on roads and railroads are shown by separate symbols. Ordinary bridges and trestles on railroads are omitted. Wherever its presence would impair the legibility of the map, the bridge symbol also is omitted.

The footbridge symbol is used only where the bridge is of some local importance—in general only where it is isolated and only where the scale allows.

Ferries.—Ferries are shown by symbol wherever the stream is wide enough to allow; where it is too narrow, the word "Ferry" is written. Names of ferries must be placed on the map.

Fords.—The symbol for a road ford is similar to that used to represent a private road. The names of important fords must appear on the map.

Trails.—In mapping trails, the surveyor must consider their relative importance as a means of communication. Thus in mountain and desert sections and in heavily wooded areas, especially where sparsely settled and where traveling is done largely along trails, he should take pains to map each important trail, giving its name, if known. In the more densely populated districts, where railroads and roads are plentiful, only such trails as lead up mountains or through unimproved areas not readily accessible otherwise are shown. A mere "way through" not regularly traveled does not constitute a trail.

Poor pack trails and all foot trails are inked in the dot symbol and good pack trails in the dashed symbol. Where the classification is uncertain, the dashed symbol is used.

Steamboat routes.—All steamboat routes on lakes and rivers, over which regular public service is maintained by ferries or passenger boats, are indicated by fine dashed lines and the words, "Steamboat route."

Canals and ditches.—Canals, whether for navigation, irrigation, or drainage, are shown by a double-line symbol if their actual width can be indicated on the scale employed, otherwise by a single blue line. Abandoned trunk canals constituting prominent topographic features are indicated by the long-dash symbol.

In the mapping of irrigation ditches, both mains and important laterals are shown; the mains are so designated. Canals and ditches are inked in blue.

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Canal locks.—The lock symbol should point up current. The symbol for canal locks is inked only so far as it can be engraved legibly at the publication scale, and the upper and lower gates are inked separately only where both gates can be shown legibly.

Aqueducts, water and oil pipes.—Only the principal aqueducts and pipe lines are shown.

Power-transmission lines.—The alinement of high-voltage (100,000 volts or more) trunk power-transmission lines should be obtained in the course of the field survey and shown on the field sheets. Sections of power-transmission lines within corporate limits and lateral distribution systems should be omitted. Trunk lines are usually built on private right-of-ways and, in most parts of the country, are placed on steel towers. Power lines may be inked in black, but if they are in close contact with other cultural features they should be inked in red for clearer recognition. Power lines are not shown in sections of heavy culture.

Tunnels.—Tunnels of all kinds, whether for railroads or canals, are shown by the tunnel symbols. The route of the tunnel is indicated by double broken lines. Railroad or road tunnels are inked in black, aqueduct tunnels in blue.

Dams.—Permanent dams in streams, lakes, or reservoirs are indicated by a heavy line. Where a road follows the top of the dam, the road is shown in its correct place and the road line on the upstream side is thickened to represent the dam. The dam should be inked to its mapped length only.

Reservoirs.—The shore line used to represent a reservoir should correspond to the normal full state of the reservoir that is controlled by the dam. Artificial reservoirs surrounded by dams on all sides are not enclosed by the dam symbol but are outlined in blue, like lakes and ponds. Small reservoirs are further emphasized by a blue water lining.

Levees.—Levees are shown on United States Geological Survey topographic quadrangles by hachures or contours printed in brown (pl. 4), and when these sheets are used as a base map, this symbol is used. The symbol to be used on plane-table sheets is shown on plate 2 and should be inked in black.

Wharves, etc.—Wharves, docks, jetties, breakwaters, and similar structures should be indicated by firm sharp lines and shown with such detail as the scale of the mapping allows. These are inked in black, in outline only, as plotted to scale in the field. A narrow wharf or pier, however, is represented conventionally by a double line about the width of a narrow road. Jetties and breakwaters are inked in single heavy black lines.

Lighthouses, etc.—All lighthouses and lightships must be located on the map and shown by their respective symbols.

Lifesaving stations.—Lifesaving stations in general are shown by the house symbol, followed by the letters LSS; but lifesaving stations of the Coast Guard are shown by the same symbol followed by the letters CG.

Cemeteries.—Cemeteries are shown with their actual outlines and the name inserted if the cemetery is well known and there is space, otherwise a cross is placed within the outline, or the letters CEM alongside. Private cemeteries that are too small to plot to scale may

be shown conventionally by a small square enclosing a cross, but they are omitted unless they constitute landmarks in a thinly settled country.

Airports and landing fields.—Boundaries of all airports and landing fields are indicated, including municipal, commercial, and private airports; Department of Commerce intermediate landing fields; marked auxiliary landing fields; army airfields; and naval air stations. The symbol used for the boundary is that shown for a cemetery or small park on plate 5.

Mines and quarries.—Mines and quarries are indicated by the pick-and-hammer symbol. In sparsely settled sections, where there is little culture to be represented, isolated mines, quarries, and even prospects (sawbuck cross) that constitute landmarks and are widely known, are shown, together with their names.

Oil and gas wells.—Producing oil and gas wells are indicated by a special symbol. Where such wells are so numerous as to be practically indistinguishable, only the approximate outline of the pool (by dashed lines) is shown.

Furnaces and smelters.—No additional conventional sign other than that for a house is used to represent furnaces, and in many areas it will not be practicable or desirable to name them. In sparsely settled sections, however, the furnaces may be the most important and persistent landmarks, and they may have well-recognized names which cling to the localities even after the practical disappearance of the furnaces themselves. In such areas, therefore, it is desirable that the names be given, even though nothing remains but a ruined stack. The same rule applies to smelters, except that those shown on the map should be restricted to smelters in active or prospective operation.

Coke ovens.—Only coke ovens connected with mines in operation are shown on the maps.

DRAINAGE

The drainage features of the terrain include those features representing water, such as flowing streams, lakes, and shore lines, and those indicating some degree of wetness, such as intermittent streams, marshes, and glaciers. The drainage features are shown on all soil maps by standard symbols (pl. 3) or by means of other conventions as described in the text.

Tidal shore lines.—On all soil maps the line of mean high tide is considered the shore line. In determining the margin of mean high water, the highest (semimonthly) tides are excluded and an average taken of the usual high tides as generally marked by the limits of vegetation. The charts of the United States Coast and Geodetic Survey are frequently useful in checking the position of shore lines.

Shore lines of all waters should be inked in a firm continuous blue line and not broken for wharves, piers, and similar structures that may be built over the water. Such structures are inked in black. Sea and retaining walls that are simply artificially constructed parts of the shore lines are inked in blue.

Marshes in general.—Fresh-water and salt-water marshes recognized as soil types or land types are represented by their respective symbols. Marshes on low coasts, as a rule, are traversed by a network of tidal channels. Unlike the rills in mud flats, these channels

are fairly permanent in location, and those that exist at mean high tide are mapped individually so far as the scale allows. Tidal marshes are represented by the proper symbol.

Submerged marsh.—Marshlands that are partly submerged for many months each year are differentiated from ordinary marshes and are represented by inking grass tufts in blue (no horizontal lines) on the water surface.

River shore lines.—The mapping of broad rivers, especially of the braided type, offers a perplexing problem to the surveyor, because of their periodic fluctuations and corresponding changes in width. As a general rule the width shown should correspond to the normal stage, defined as that water level which remains nearly stationary for the greater part of the year. This excludes all stages of relatively short duration resulting from floods, whether periodical or out of season, and all low-water stages. The normal stage will, in general, be found to exist for about 9 to 11 months for most streams in the relatively humid sections. If any stage of water other than the normal has been mapped by other Government agencies, instructions should be sought as to the availability and best use of such cartographic material.

In areas where the flow of rivers, though active for brief periods, dwindles or ceases altogether for many months, the normal or prevailing stage is very low. Thus, rivers like the Platte and much of the Missouri are normally braided and are represented as such on the map. Where the streams have wide bottoms of unstabilized, shifting sediments, the land is shown as sand or riverwash with the principal channels indicated as intermittent or perennial streams, double line or single line as may be required. Other bodies of land within the normal flood plain, having trees or other stabilizing vegetation, or cropland are shown as definite soil types or phases. Rock outcrops are shown appropriately as such. Many rivers in desert areas are no more than broad sandy washes, except for brief periods, and they are shown by strips of sanding.

Natural lakes.—The shore line used to represent a natural lake or pond is that corresponding to the normal stage of water and not necessarily the exact shore line that is found at the time of the survey, if made during a period of flood or extreme drought. An effort should be made to ascertain the shore line of the normal stage, as usually marked by a line of permanent land vegetation. The shore line used to represent a large lake that is subject to a gradual rise or fall over long periods is that found at the date of survey. This date should be indicated on the water surface in ink.

Artificial lakes.—The shore line of an artificial lake is the line that represents the margin of the water surface at the full normal stage of the lake, as controlled by the dam.

Island shore lines.—The shore line of an island must be that corresponding to the stage of water used for the adjoining mainland shore line. Islands exposed only at a stage of water below that accepted for the mainland shore line should, therefore, not be mapped.

Drainage classification.—The field sheets must indicate clearly all streams as perennial or intermittent. Great care must be taken in

the field with drainage, because few data exist for checking it accurately in the office.

Perennial streams.—A perennial stream is one that flows throughout the year, and it is represented on the field sheets by a solid blue line. All perennial streams should be shown on the field sheets, even though, on the published map, it may be necessary to omit minor ones which cannot be printed within the publication scale. Although the map should not be overburdened with insignificant rills and forks, such as abound in well-watered sections of the country, it is important that the perennial drainage system be made complete. As the purpose of this symbol is to show where running water may be found, it should be indicated on the field sheets only where the perennial character of the stream is reasonably established. In semiarid or arid sections, streams having perennial water holes in their beds, even though water is not flowing everywhere on the surface during dry periods, are shown as perennial streams on the soil map. In cases of doubt, occasional inquiry may be necessary to supplement field observations.

Perennial streams should be inked with a solid blue line increasing in width with the size of the stream but nowhere so broad as to be equivalent to double lines. Care should be taken not to draw streams to the edge of the map with a width that cannot be continued properly on the next map. Stream lines should taper toward the sources of the streams but should remain deep and strong in color to the head.

Double-lined streams.—Streams of sufficient width should be shown by two lines drawn to scale. No stream should be double-lined, however, unless its actual width can be shown to scale without exaggeration.

Intermittent streams.—An intermittent stream is one that is dry for a considerable time each year, ordinarily for 3 months or longer. Such streams are shown on the map by the dash and three-dot symbol. Aggraded flats and valley floors devoid of well-defined stream channels or scars are not properly shown with drainage lines running through them. In sections where both perennial and intermittent streams abound, the inking must be complete and clearly distinct as to each kind. If the proportion or amount of intermittent drainage is so large that the field drafting of the dash and three-dot symbol becomes burdensome, the copy can be made clear for inking by means of an overtracing (information sheet) showing only the perennial streams, with a statement that all other streams are intermittent.

On the field sheets, all clearly observable and mappable intermittent drainage should be shown, even though some may need to be omitted on published maps. The complete drainage system, perennial and intermittent, has an important relationship to the pattern of soil types and phases. The map of the drainage systems suggests the general physiographic features of the country and is a valuable adjunct to the soil map itself.

Disappearing streams.—Many streams, especially in sections underlain by limestone, sink abruptly into caverns and may continue their courses for long distances through subterranean chan-

nels. Special care must be given to the mapping of streams of this type and the points of disappearance and reappearance accurately located. Only the surface drainage is shown.

Springs.—The importance of representing springs on a map is dependent on their relative usefulness as a part of the water resources of the area. Springs must be located with great care on maps of arid sections, where they are of vital importance and where their omission or erroneous location may greatly reduce the usefulness of the map. In such places, the name by which each spring is known is indicated on the map. Intermittent springs or those having salty or otherwise undrinkable water are so designated on the map. On maps of well-watered sections, conspicuous springs are shown by symbol, and by name if locally recognized, but numerous springs need not be shown. The copy must be clear for these symbols in order to be distinct, and if necessary the presence of springs should be noted on a supplemental sheet. Walled-in springs are shown as wells, by a blue circle, but a spring that is a source of a stream is shown by a blue circle with the outlet stream as plotted.

Wells and water tanks.—The importance of wells and water tanks, like that of springs, depends entirely on their relative usefulness as a part of the water resources of the area. In the semiarid sections both wells and tanks are shown. Artesian wells are so designated.

Intermittent and dry lakes.—Shallow lakes and ponds, that are dry for many months each year are typical of some sections, and all those not too small for the scale of the field sheets must be shown. Dry salt lakes and "alkali" flats, although not intermittent in the usual sense, are so closely related to intermittent lakes in appearance and formation that they are shown by the symbol for intermittent lakes. Both types are shown by a dashed outline with the surface indicated by hachures. Those of any size and importance must be fully described in supplemental notes, as to drainage and other physical characteristics.

Water lining.—Oceans, bays, lakes, ponds, and broad rivers are water lined in blue on the field sheets, only in places where the copy otherwise would be ambiguous.

RELIEF

The relief on topographic quadrangles is expressed by contour lines, and when these sheets are used as a base map for the soil data, the contours are generally published on the soil map with any necessary corrections.

When it is necessary for the soil surveyor to prepare his own base map, the large and important features of relief, such as mountain ranges, plateaus, bluffs, basins, valleys, and gulches, are indicated on the map by the position of the name of the feature. Small mountains and hills, where of sufficient importance to be shown, are indicated by hachures inked in black. Bluffs, cuts, depressions, fills, mine dumps, and narrow steep ridges are shown either by the standard symbols shown in plate 4 or by means of other conventions described in the text.

Depressions.—Natural depressions or sinks, such as occur in limestone sections, are indicated on the field sheets by hachures if the scale employed allows, otherwise the diamond-shaped symbol is used. (See also optional and special symbols for use on field sheets, pl. 6.)

Mine dumps.—The symbol for mine dumps is used when the dumps are not extensive enough to justify their mapping and inclusion in the legend as land types.

BOUNDARIES, MARKS, AND MONUMENTS

Boundaries, marks, and monuments to be shown on soil maps are indicated by the standard symbols, illustrated in plate 5, or by other conventions described in the text.

Civil boundaries.—All civil boundaries, whether national, State, county, district, civil township, reservation (national or State parks, forests, monuments, bird and game preserves, Indian, military, or lighthouse), land grants, corporations (city, town, or borough), parks, and cemeteries, are shown on the map by their respective symbols. Special effort should be made by field parties to locate such boundaries with accuracy and directly from triangulation points or traverse lines if practicable.

Necessary descriptions, survey notes, and plats of all lines of importance should be consulted. Data on national or State reservation boundaries can be obtained from headquarters prior to the beginning of the field work. Data on minor civil subdivisions can be procured locally while the survey is in progress. Many boundaries are obscured or obliterated by natural causes or artificial works; some were indifferently marked when established; and others have lost some or all of their marks. In many instances, information from local settlers may prove of value and save time and effort in the search for obliterated lines. Although the surveyor must avail himself of such information, the word of a resident is not to be taken as authoritative but merely as supplementing information from official sources.

Where lines are found incorrect in azimuth and distance, as the result of field errors, it is a fundamental principle that the line marked on the ground is the *de facto* boundary and is to be shown on the map in its actual position, regardless of the statute. This principle may necessitate the accurate location of a number of monuments, so that each error in the alinement may be designated at the particular spot at which it exists. Although some of the old Government Land Office plats may show sections to be regular, they may be irregular and must be shown on the map as nearly as possible according to the actual location of section corners on the ground.

Some civil boundaries are defined by statute to follow natural boundaries, such as streams or divides between drainage basins. Those following large rivers should be given special attention, as they may be variously defined, as the middle of the stream, its main current, or one of the banks. United States Geological Survey Bulletin 689 should be consulted as to State boundaries, and any doubtful application of the statutes should be fully investigated. Although the surveyor is to identify the boundary line on the ground and then plot it on the map, ground conditions are sometimes found to be uncertain or lines indefinite or unmarked, as where they lie in streams with shifting channels or banks that are difficult to determine. Again the line may not have been accepted by those living on both sides of it or by the proper county or State authorities, and it may be in dispute or even in court. The location of the State boundary line should, therefore, be subject to special attention.

The following general principles may be stated: (1) A line marked on the ground and once accepted by competent authority is the real boundary, regardless of a statute (apparently) to the contrary. (2) Where the description of a particular bank or point in a stream is indefinite in wording or difficult of application, past practices or rulings must be sought. (3) Early Supreme Court decisions have ruled that a boundary moves with a gradually shifting channel or bank but does not follow sudden shifts or cut-offs, and these rulings have in general been followed in recent decisions. (4) If a statute defines a boundary line as coincident with some channel or other part of a river, the location of the river itself at the time the statute became effective should govern, unless there has been a gradual change in the position of the river, as just indicated. The generally accepted location of the rivers that form State boundaries at or near the time of the enactment of most of the statutes defining the boundaries may be found on the plats of the General Land Office, that were prepared at about such times. Supreme Court rulings must govern if they have been made, but few decisions that affect the details needed on soil maps have been handed down by the Court.

Civil boundaries should be verified before inking, as a precaution against errors in the interpretation of penciled field copy. Where civil boundaries of different classes coincide for a distance, the symbol of the major subdivision takes precedence, except in instances where greater clarity will be attained by other procedure. Where it is obvious that a civil boundary follows a stream or road for a short distance, the boundary symbol may be omitted to avoid confusion. In some places, however, clearness may be increased by placing the boundary symbol (in red) immediately alongside the stream or road.

County subdivisions.—Only such county subdivisions are shown on soil maps as appear reasonably permanent in character and location, and those subject to frequent changes at county elections are excluded.

In general, counties are divided into smaller units. These bear different designations in different States, or even different designations within different counties of the same State. In the States organized from the public domain and surveyed under the public-land system, one or more of the so-called congressional townships has usually been taken as the unit of organization. In New England, and in other parts of the country affected by New England migration, are found town units, in which are vested many of the powers that in the South and in the newly settled West pertain to the county. Some counties in Maine, New Hampshire, and Vermont, in addition to the towns and cities, the only regular subdivisions, have partly organized or unorganized territory laid off by these States as plantations, gores, grants, purchases, locations, and islands.

The following summary, taken from census reports, gives the names of the primary divisions of the county, or its equivalent, in the several States and Territories:

Alabama	Election precincts.
Alaska	Recorders districts.
Arizona	Election precincts.
Arkansas	Townships.
California	Judicial townships.

Colorado	Election precincts.
Connecticut	Representative districts.
Florida	Election precincts.
Georgia	Militia districts.
Hawaii	Election districts.
Idaho	Election precincts.
Illinois	Townships and election precincts.
Indiana	Townships.
Iowa	Townships.
Kansas	Townships.
Kentucky	Magisterial districts.
Louisiana	Police jury wards.
Maine	Towns and cities.
Maryland	Election districts.
Massachusetts	Towns and cities.
Michigan	Townships.
Minnesota	Civil townships, townships, and ranges.
Mississippi	Beats.
Missouri	Townships.
Montana	School districts, townships, and election precincts.
Nebraska	Townships and election precincts.
Nevada	Townships and election precincts.
New Hampshire	Towns and cities.
New Jersey	Townships.
New Mexico	Election precincts.
New York	Towns and cities.
North Carolina	Townships.
North Dakota	Civil townships, election precincts, school townships, and school districts.
Ohio	Townships.
Oklahoma	Townships.
Oregon	Election precincts.
Pennsylvania	Townships, cities, and boroughs.
Puerto Rico	Barrios.
Rhode Island	Towns and cities.
South Carolina	Townships.
South Dakota	Civil townships, election precincts, school townships, and school districts.
Tennessee	Civil districts.
Texas	Commissioners' precincts and justices' precincts.
Utah	Election precincts.
Vermont	Towns and cities.
Virginia	Magisterial districts.
Washington	Election precincts.
West Virginia	Magisterial districts.
Wisconsin	Towns.
Wyoming	Election districts and election precincts.

Public-land lines.—In the so-called public-land States all lands that have at any time been subdivided or "sectionized" by the General Land Office must be shown on the soil maps by indicating such township and section lines as have been run and have been approved by the Land Office and are not under suspension, and by showing with a distinctive symbol such public-land survey corners as have been found in the course of the survey, after a reasonably diligent search and thorough inquiry. Theoretically all corners are marked on the ground, but in practice many are difficult or even impossible to find.[9]

In well-settled parts of the country, where land lines often become property lines and sections are generally marked by roads and fences, the construction of a public-land survey net is comparatively simple. But in unsettled country or in settled areas where the roads or

[9] For a description of the public-land survey system, see Beaman (*1, p. 368*).

fences seldom conform to section lines, it is necessary to find on the ground and locate on the map enough section corners to enable the cartographer to construct a land net built up from the Land Office plats and notes and tied to the located section corners. In some instances the old Land Office surveys are inaccurate, and the plats in no way conform to the actual section corners on the ground; therefore great care must be taken to locate as many corners as possible for the preparation of an accurate grid.

In order to avoid any confusion with other cultural features, all public-land survey lines are inked in red on the field sheets, except where roads or canals are coincident with them. Section lines are inked in fine lines, and township lines are distinctly heavier. Only those township and section lines and parts thereof that have been surveyed and approved by the General Land Office, are not under suspension, and are indicated on the land plats by solid lines, should be inked on the maps. The fractional distances for section lines less than a mile are usually found on the land plats, and where accurate plats are available, such distances afford the means for plotting fractional land lines. Land lines broken at water surfaces on account of shore meanders should be broken as shown on the plats. Meander lines should not be plotted or inked, and section lines should not, of course, be drawn across meandered streams or lakes or meander land.

Search for public-land corners.—The time warranted in search for obscure corners will be determined by the probable regularity or irregularity of the net and the proximity of corners already found. The lesser local information at hand, the greater the necessity for pioneer hunting for the needed land ties. Diligent search must be made on the ground for all corners believed to exist near the line of survey, especially those near the primary traverse.

In a region where there are few roads on section lines, assistance in finding corners may be had by using an oversheet of tracing paper or cloth, upon which has been laid out to field scale either a single typical township or an entire land net covering the area to be mapped, built up in advance from the Land Office plats and notes. Such a tracing, placed in position over a field sheet as soon as the first land corner has been plotted, will indicate graphically the theoretical location of all other corners; and as more corners are found the further placements of the tracing become more serviceable as a guide.

The field man must be thoroughly conversant with the system of rectangular land surveys and the intricacies peculiar to it. Acquaintance with the standard monuments used for the several classes of land corners, their marks, and their bearing trees, as well as with the manner in which blazes on trees become overgrown with bark, will prove most useful both in searching for corners and in determining their authenticity where this is in doubt. Public-land corners that have been found in the course of field work are inked in red with the symbol for found-land corners. (See also pl. 6 for special field symbols.)

Township and range numbers.—Township and range numbers are placed along the margin of the map opposite the middle of each township, with the township numbers along the right and left and the range numbers along the upper and lower margins. If the num-

bering is irregular, however, the numbers are placed within the townships. Most field sheets are of one township, but on field sheets that cover two or more townships or fractions thereof, the township and range numbers are placed opposite the lines bounding the townships. Numbers and names of base lines and principal meridians are shown.

Boundary monuments.—All monuments on national, State, and national-park boundaries are located in the field and represented on the map with the side of the open square oriented with the direction of the boundary line and with its designating number alongside. On other boundaries, monuments occupying controlling positions, such as corners or important crossings, should be located.

National, State, and national-park boundary monuments, with designating numbers alongside, are inked in black, whereas boundary monuments on other lines, with designating numbers, if obtainable, are inked in red.

Location and mineral monuments.—Monuments erected as permanent reference marks for the location of mineral and other claims (often designated as U S L M's or U S M M's) should be located with the same accuracy as land-survey corners and, if practicable, by plane-table triangulation. They are shown on the field maps with their designating numbers.

Authority is vested in the United States mineral surveyors to establish "mineral monuments" where no land-survey corners exist in the immediate vicinity of claims and to number them serially in each State. A former practice was to establish so-called location monuments in each separate mining district, numbered serially in each district, and those already established are still so designated. A careful distinction must be made between the two systems, and the numbers of the monuments must be obtained. The abbreviations may be illustrated by these examples, U S L M 2, and U S M M 23 7.

Triangulation points and transit-traverse stations.—The triangulation points and transit-traverse stations which have been tied to the traverse are indicated accurately on the field sheets in red ink with the open triangle and dot symbol. The names of triangulation points and the numbers of transit-traverse stations are also inked in red.

Level benchmarks.—Level benchmarks are not to be shown on the field sheets, as their positions have not been determined geodetically, as have the triangulation and primary traverse stations. Their elevations only have been determined, and, therefore, they are of no value to the cartographer in the adjustment of the traverse.

Field men must learn to distinguish triangulation stations, transit-traverse stations, and level benchmarks one from another. Figures 10 and 11 show the standard markings of the tablets used by the United States Coast and Geodetic Survey and the United States Geological Survey, respectively.

MISCELLANEOUS SYMBOLS

In addition to the standard symbols already discussed, several others are used on soil maps where necessary (pl. 6).

Rock outcrop.—Occasional rock outcrops, too small to show as land types, are shown by symbols.

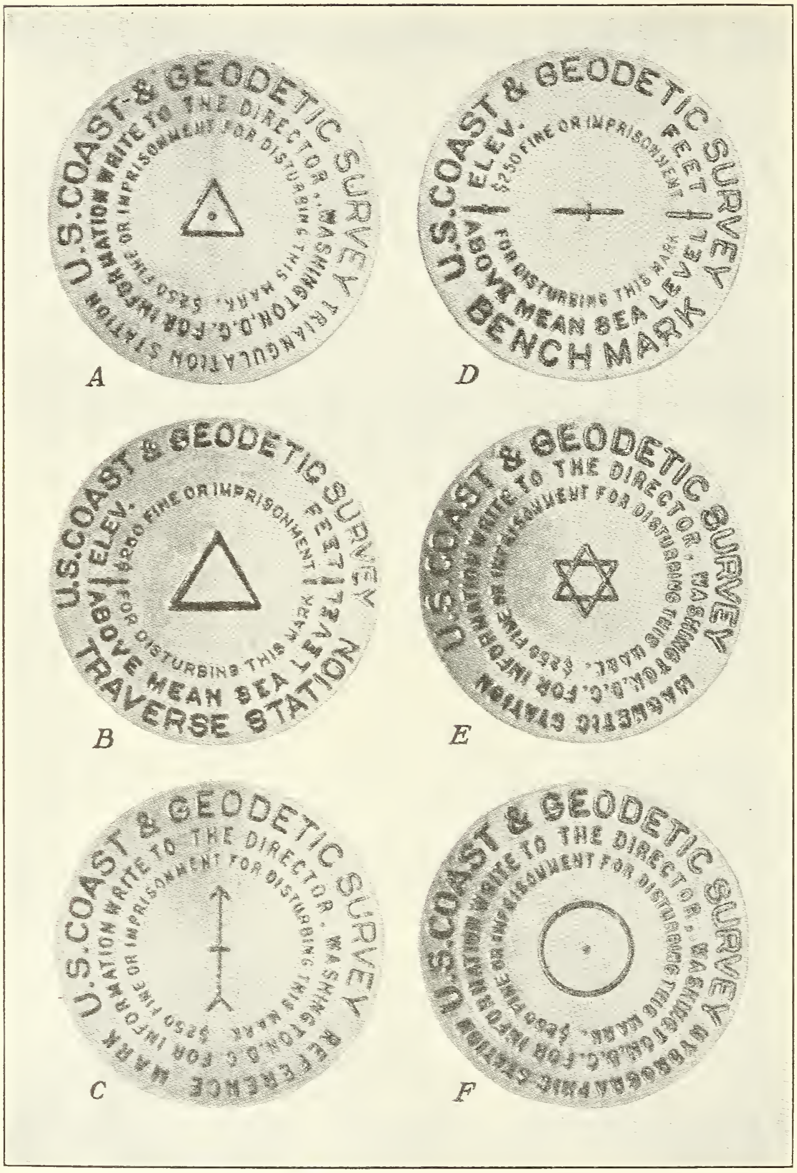

FIGURE 10.—Standard station marks of the United States Coast and Geodetic Survey: *A,* Triangulation station mark; *B,* traverse station mark; *C,* reference mark; *D,* bench-mark; *E,* magnetic station mark; and *F,* hydrographic station mark.

(Courtesy United States Coast and Geodetic Survey)

FIGURE 11.—Geological Survey station marks: *A,* Triangulation or transit traverse mark. (When used as the latter, the letters "TTR" and the number of the station are stamped on the tablet.) *C,* Level benchmark. (Sometimes, at a later date, this benchmark may be made a transit traverse station, and it is then stamped with the letters "TTR" and the number of the station. *B* and *D,* Copper temporary level benchmark.

(Courtesy United States Geological Survey)

Stone, gravel, and chert fragments.—The symbols for stone, gravel, and chert fragments are used to show stony, gravelly, and cherty areas which are not extensive enough to be included in the soil legend as distinct phases or for areas too small to be delineated by boundaries on the scale employed. In the descriptive legend for the area, the chief of party must see that these symbols are defined, quantitatively and qualitatively, according to the needs in the particular area.

Sand spots.—A symbol is used for sandy areas under the same circumstances as the stone symbol for stony areas.

Made land.—The symbol for made land is to be used when the areas of such land are too small for mapping as a land type.

OPTIONAL AND SPECIAL SYMBOLS FOR USE ON FIELD SHEETS

The use of the optional and special symbols on field sheets as shown on plate 6, is determined by the scale employed in the field mapping, the detail required, and the complexity of the map. A few, such as those for roads, foot traverse lines, power-transmission lines, and survey corners, should be used in lieu of the standard symbols, as it is more convenient to draw them clearly. Deviations from the standard symbols, illustrated in the accompanying plates, should not be made except under unusual circumstances and with special instructions.

NAMES

Before leaving the area, the surveyor should obtain correct names of all features requiring them. The general policy is to conform to local usage, but at least two independent authorities for each name and spelling should be obtained. In instances of differences in usage, spelling, or application, decision must be reached on the basis of all pertinent facts, including the predominance of local usage. Names of cities and physiographic features must conform to the decisions of the United States Board on Geographical Names.

The importance of a complete and authentic record of place names is so great that nothing should be left to memory, and all necessary notes should be made and all names recorded as soon as they are obtained. The usefulness of the soil map depends, in large measure, on the ease and accuracy with which the reader can locate specific bodies of land. This is greatly facilitated by a reference to place names of prominent features.

Names to be shown.—Names of the following features are shown on the map:

Cities, towns, villages, and other settlements, including all country post offices and railroad stations. Where the name of a railroad station differs from that of the corresponding post office, both names are shown. The one most widely known is given the greater prominence, and the other is followed by P. O. or Sta. as appropriate.

Country schoolhouses.

Country churches.

Experiment stations and substations.

Isolated ranches and resorts, constituting important landmarks in sparsely settled districts.

Important public institutions, such as universities, colleges, and State hospitals.

Railroads (steam or electric). In addition to the name of the railroad, it is desirable, as a rule, to give the name of the branch, line, or division, for complete office identification.
United States highways.
Bridges, ferries, and fords.
Through trails.
Principal steamboat routes on large lakes and rivers.
Large canals, ditches, aqueducts, etc.
Tunnels, dams, lakes, reservoirs, and other public works.
Lighthouses, lightships, and lifesaving stations.
Large parks and cemeteries, if the scale will allow.
Airports and landing fields.
Isolated mines, quarries, prospects, and oil wells.
Isolated furnaces and smelters.
Civil divisions.
Reservations.
Hydrographic features.
Prominent features of relief.
Springs, wells, and tanks, especially in arid sections where these features are of vital importance.

LETTERING OF FIELD SHEETS

It is expected that every field man shall have learned to draw sufficiently well to ink his sheet in a clear and distinct manner and letter it with some regard to neatness and graphic effect, as the appearance of an otherwise well-inked sheet is marred by careless or indifferent lettering. Simple accuracy, neatness, and clearness are necessary, rather than fine draftsmanship. An example of a soil surveyor's field sheet, using the several symbols correctly, is shown in plate 10. Such field sheets must carry the data necessary for the construction of a lithographic map as shown in plate 11.

All geographic names shall be in black ink, and names solely for use during the survey shall be in red ink.

LETTERING OF THE MAP FEATURES

Lettering on original or on oversheet.—The lettering is usually placed upon the original field sheet, but if the detail of the map is such that it would be difficult to place the lettering without obliterating some feature of the map it should be done on tracing cloth registered over the field sheet with a separate tracing or oversheet for each field sheet.

Style of lettering.—The lettering should be neat and graceful and should conform in style to the standard lettering shown in plate 7. The styles of lettering used on published maps are shown in plate 8. Strict adherence to simplicity must be observed; no illuminated or German text, old English, or what is known as "fancy printing" should be used. The use of capitals and lower-case letters and the gradation in sizes of letters will depend on the relative importance of the features named.

All place names, such as those of towns, schools, and ranches, and those of topographic or land features, such as mountains, canyons, draws, washes, islands, points, and bends, are lettered in upright block capitals, or lower case, as appropriate.

Names of civil divisions, such as counties, townships, and reservations, are lettered in upright block capitals.

Names of routes of communication, such as railroads and highways; of public works, such as bridges, ferries, and dams; of public

institutions, such as cemeteries, asylums, and universities; and of mining features, such as mines, furnaces, and smelters, are lettered in small slanting block capitals.

Names of hydrographic or water features, such as creeks, runs, lakes, pocosins, bogs, marshes, bays, and oceans, are lettered in slanting block capitals, or lower case, as appropriate. Streams should be named throughout their course.

Position of lettering.—By their direction and proximity, names should indicate clearly the objects designated. The lettering should be so placed, as far as practicable, that it can be read easily when the sheet is held with the top (the north end of the map) away from the observer, and as nearly parallel with the north side of the sheet as the work will allow.

MARGINAL LETTERING ON FIELD SHEETS

Name of area.—The name of the area or county should be placed on the upper margin of each sheet.

Sheet numbers and diagram of area.—Each field sheet should be given a number lettered clearly on the margin beneath the name of the area or county. A diagram showing the arrangements of the sheets should also be shown, preferably on each sheet. If there are a great number of field sheets covering the area, however, it will be permissible to show the diagram on a single separate sheet.

Township and range numbers.—Township and range numbers, in the form T. 5 S., R. 7 E., are lettered on the map margin opposite the center of each township or part of a township.

Scale.—The scale of the field sheets is indicated clearly on the margin of each sheet or, if there are a great many sheets, on the diagram sheet.

Declination.—An arrow showing the direction of magnetic north, as determined by the compass needle, must be shown on the margin of each field sheet. In addition, the magnetic declination should be given when this can be determined.

Author diagram.—An author diagram should be added on each field sheet or on the diagram sheet, showing the respective areas mapped by the different field men. If the traverse was run by a field man other than the one who mapped the soils, this fact should be indicated.

Credit for outside data.—Credit should be given for any outside data used in the construction of the field sheets, whether from Federal, State, or private sources. Such credit may apply to the base map, boundary lines, shore lines, or other data.

Date of survey.—The date of survey should be given on each sheet. The date or dates used should refer to the mapping of the field party and not dates for outside data, which should have been examined and corrected to the date of new work before being incorporated.

The marginal lettering for the published map is shown in plate 9. The chief of party must be certain that the necessary data are included with the field sheets.

CONSTRUCTION OF SOIL-MAPPING LEGEND

A complete descriptive legend, including all soil separations and all symbols of whatever kind to appear on the soil map, must be prepared and made available to each surveyor before any actual plotting of soil boundaries can be undertaken. The first duty of the chief of party on entering a new area is the preparation of such a legend. As the work progresses, especially in a relatively new area, this legend will need to be revised from time to time. Whenever possible the preliminary work, at least, is done in the company of the regional inspector or assistant inspector, but frequently it will be necessary for the chief of party to undertake this work in the absence of the inspector. The chief of party will utilize the services of other competent and experienced scientists who may be assigned to his party, but in the beginning it is unnecessary to devote the time of the entire staff to this work.

First, the chief of party must have clearly and definitely in mind the objective of the soil-survey project, in order that he may know what degree of detail is to appear on the maps and the scale to be employed in the field mapping. Usually the chief of party will be instructed on these points, and his problem will be to determine how the various features may be shown on the map, clearly and definitely, without oversimplification on the one hand or excessive detail beyond the limits of clear cartography on the other.

Technically, this problem consists of a determination of the mapping units and symbols, which will be shown on the map. These units must be decided on, thoroughly examined at several points of their occurrence, and clearly described in full detail before any mapping is undertaken. It is desirable that all soil units in a given area be examined and described in advance of mapping. Sometimes, however, this is impracticable. Therefore, it is sufficient to examine and describe the principal soil units, leaving some of the subordinate separations to be determined later, as the work progresses.

If the area to be surveyed lies adjacent to areas previously surveyed, these should be visited first, and at least the principal soil types already established and described carefully examined in the field. If any area in the same general region has been previously surveyed, the reports and maps should be thoroughly studied and, if possible, the area visited for examination of the soil profiles.

On entering the new area to be surveyed, the chief of party should scout the area as a whole, in order to get a general picture of the soils, relief, vegetation, agriculture, and other physical features, which must be shown on the map. Wherever possible this will be done in company with the regional inspector or his assistant and with competent State or local representatives. It is desirable that the chief of party reach the area to be surveyed in advance of his assistants so that he may have sufficient time to familiarize himself with the area, to collect the necessary data, to prepare a preliminary field legend for his assistants, and to plan a program of work. If any members of his party arrive with him, they may assist him with this preliminary work or proceed to the preparation of the base map.

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EXAMINATION AND DESCRIPTION OF SOILS

After the surveyor has a general knowledge of the area to be surveyed, in regard to soils, relief, and other physical features which must be shown on the soil map in order to reach the objective of the project, he must determine what soil types and phases occur in the area and provide definitions of them. If the area to be surveyed lies adjacent to areas previously investigated and surveyed, the preliminary scouting may disclose that rather precise definitions of the principal soil types are available already. If the area to be surveyed lies apart from other detailed soil surveys, it may be that several of the soil types have never been defined precisely, or even defined at all. Even though a soil type has been defined, its morphology must be examined carefully, in order to be certain that the description provided in the field pertains definitely to the type as developed in the particular area, including any slight variations in its characteristics as compared to those developed elsewhere. That is, Orangeburg sandy loam in one area may have slightly different characteristics from those developed elsewhere, and it is of especial importance that the mapping legend include a precise description of the soil type as developed in the area being surveyed.

The main task of this phase of the field work is to discover and describe the principal mapping units. If the entire area lies in one physiographic region, it may be considered as a unit; otherwise it must be divided into its individual natural landscapes and each of these investigated separately. The first soil to examine and describe is the normal soil for the natural landscape, or landscapes, if there is more than one in the area.

The normal soil is the one having a profile in equilibrium with the two principal forces of the environment—native vegetation and climate—with the other factors—relief, parent material, and age—in a neutral position. Such a soil develops on the gently undulating (but not level) upland, with good drainage, from any parent material, not of extreme texture or chemical composition, which has been in place long enough for biological forces to have expressed their full significance. It must be remembered that the normal soil may or may not be the dominant soil of the landscape, areally; it may or may not be the most productive soil for any particular group of plants; and, in some instances, it even may not be a mapping unit in the area surveyed. The characteristics of the normal soil are studied, in order to discover the general trend of the normal type of soil formation in the area. The characteristics may be equally well expressed, all or in part, in soils developed from different parent materials and which naturally constitute units of mapping.

Occasionally areas will be surveyed where there is no true normal soil, for example, in places where the entire area is low and poorly drained, or wholly located in a region occupied by parent materials which are still in process of accumulation, such as moving dune sand or recent alluvium. If an area is composed of two or more natural landscapes, two or more normal soils must be recognized.

In order to establish the principal properties of the normal soil, its profile should be examined at as many points as possible and preferably in areas of different parent materials. All common char-

acteristics of the soils developed from different parent materials should be recognized among the features of the normal soil. The establishment of the normal soil types, even though some particular areas may include little of them, is the important beginning point for any investigation of the morphology, genesis, or geographical distribution of the soils; and naturally it is the most important reference for their classification. Therefore, these characteristics should be defined with the utmost care.

Having established the normal soil, the investigator will proceed to the definition of the local units that vary significantly from the normal soil as a result of variations in one or more of the five factors of genesis. These units are the units of mapping. In determining their definition, it must be remembered that there are no definite categories in nature, but a gradual change in characteristics takes place between any two adjoining units. In some places these gradations cover only a few feet; in others they may extend for a much greater distance. Separate units cannot be established for the expression of all morphological gradations. Only distinct elements of the landscape, capable of distinct definition and cartographic expression, can be separated on a map. Examples of each such element in the area should be examined and the soil profile and other features carefully defined.

The identity of the soil unit is based on the characteristics of the soil profile, yet it is not possible to examine the soil profile at every given point. The soil surveyor must learn to correlate the internal properties of the soil profile with some external features of the landscape. Each recognized soil unit should be defined in terms of mappable differentiating internal and external characteristics which will serve as a basis for a determination of the areal extension of the soil unit and for drawing the soil boundaries.

Any soil type, as it occurs in nature, has an indefinite number of profiles varying from the average or norm for the type within certain limits. Just as no white pine trees are entirely identical, no two soil profiles are entirely identical, but all the trees called white pine have the same differentiating characteristics and, similarly, all the soil profiles included in one soil type have the same differentiating characteristics. Therefore, each recognized soil unit must be examined and thoroughly described at several points, in order to obtain sufficient data for a complete description and to eliminate the possibility of a too specific or too narrow definition of the type or its norm. An examination of only one particular soil profile, no matter how carefully it has been executed, is not sufficient for the establishment of any mappable soil unit. The mappable soil unit is a geographic body and, being such, its entity can be established only on the basis of a definite repetition of certain differentiating characteristics in the soils associated with some particular environment. The particular number of examinations necessary cannot be fixed; in some instances three profiles may be sufficient, whereas in others more than a dozen may be required.

Every soil profile examined in connection with the establishment of mappable units should be carefully described. It must be remembered that the complete field description of the mapping unit is a necessary supplement to the sheets of a map. The map is useless without an explanation of all features indicated on it. The field

descriptions constitute the principal source of data for the preparation of the final report accompanying the soil map. No details should be trusted to memory alone.

The soil description must be entirely objective. Any suggestions regarding genesis or any other speculative explanation of the facts should be kept strictly apart from the description of these facts. The descriptions of soil profiles are the fundamental data of soil science. These morphological data may be supplemented with chemical, physical, agronomic, and other data, but even the usefulness of these depends almost wholly on the preciseness and completeness of the field data. The classification of soils is predicated on a knowledge of their morphology, and unless that morphology is precisely known, classification is impossible.

SELECTION OF SAMPLE AREA

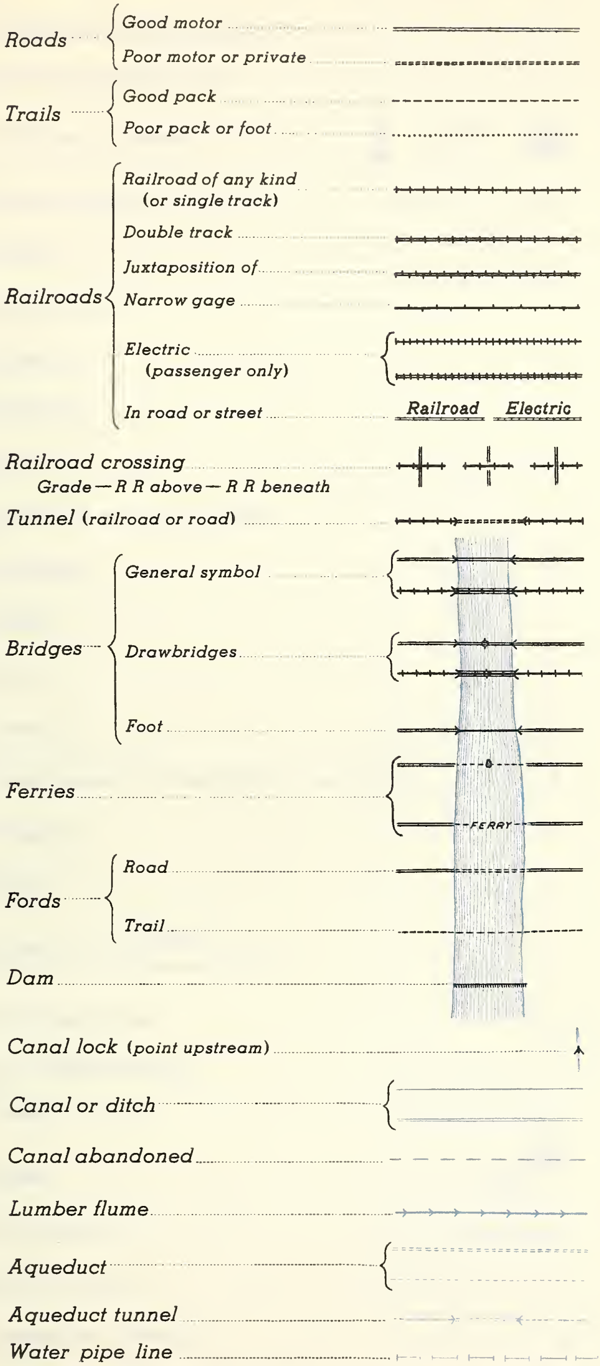
Each soil profile to be examined and described must represent the soil of some particular area of land, and great care must be taken in the selection of the places where actual examinations are to be made. A soil profile represents the synthetic expression of all the factors characterizing a particular landscape; and it must be studied in the place where the environment is average or normal for a given classificational unit. Some examinations should be made to determine the limits of variation within the units, but care must be taken to avoid gradational areas between types and in other places which may have had some unusual history. Whenever possible it is best to make the detailed and basic studies of virgin soils, but this cannot always be done in certain soil types in intensively developed sections. In timbered areas especially, virgin soils must be examined in order to determine the morphology of the upper part of the solum. The surface horizons of woodland pastures in the Podzol region, for example, may be considerably changed due to changes in vegetation, particularly on the immediate surface, brought about through the activity of grazing animals. Forest fires, especially where followed by a greater growth of herbaceous ground cover or by erosion, may alter the upper part of the solum considerably.

Examinations of soil profiles can be made from road cuts during mapping, but detailed examinations for type descriptions (and especially for soil samples) should never be made in such places unless the road cuts are unusually fresh. Exposure of the soil in a road cut to freezing and thawing and to wetting and drying leads to enormous changes in structure. In the grassland areas there is a tendency for a layer of dust to accumulate on the soil along roadsides; and in the woodland areas the much greater light intensity along the roads favors the growth of grasses and other herbaceous plants, with a decided change in the character of the surface horizons.

Before selecting the exact spot in an area of soil for making a detailed examination and a type descripton, hasty preliminary examinations of the area in several places will assist in determining the most representative spot and one free of cultural or abnormal influences. Occasionally virgin soils cannot be found or are so rare that a sufficient number of type descriptions cannot be made without including some cultivated areas. Unless the land has been abused through misuse, the morphology of all except the surface layers

[CONVENTIONAL SIGNS AND SYMBOLS]

WORKS AND STRUCTURES



STANDARD SYMBOLS FOR USE ON SOIL MAPS

WORKS AND STRUCTURES—CONTINUED

Telegraph or telephone line

Power-transmission line

Buildings in general

Railroad station of any kind

Church

Schoolhouse

Creamery

Windmill

Sawmill

Forest fire or lookout station

Cemetery

Ruins

Fort

Battery

Mine or quarry of any kind (or open cut)

Prospect

Shaft

Mine tunnel { *Opening* / *Showing direction*

Oil or gas wells

Oil or gas pipe line

Levee

Tanks

Coke ovens

Airway beacon

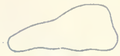
Lighthouse or beacon

DRAINAGE

Streams in general


Intermittent streams


Probable drainage, unsurveyed

Lake or pond in general
(*with or without tint, water lining, etc.*)


Intermittent lake or pond

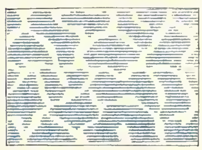

Spring


Flowing well

Wells or water tanks

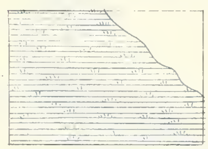
Falls and rapids

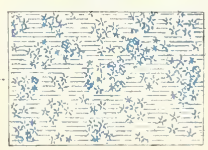

Overflowed land


Tidal flats


Marsh

- *Fresh marsh*


- *Salt marsh*


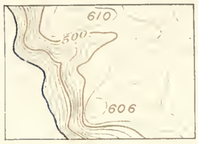
- *Cypress swamp*


STANDARD SYMBOLS FOR USE ON SOIL MAPS

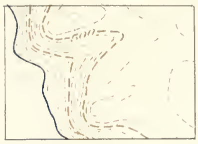
RELIEF

(shown by contours, form lines, hachures, or shading as desired)

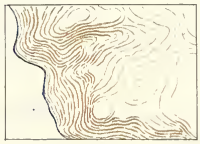
Contours (*blue if under water*)



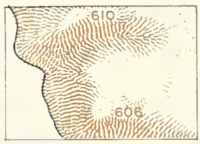
Contours (*approximate only*)



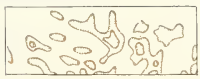
Form-lines (*no definite interval*)



Hachures



Depression contours



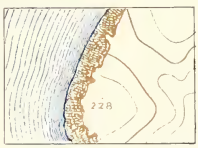
Depression symbols

Cuts

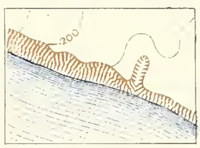
Fills

Mine dump

Bluffs — *Rocky* (*or use contours*)

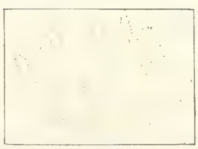


Bluffs — *Other than rocky* (*or use contours*)

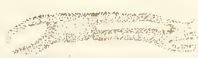


Narrow steep slopes

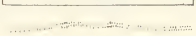
Sand and sand dunes



Washes



Levee



(*On U S G S topographic maps*)

STANDARD SYMBOLS FOR USE ON SOIL MAPS

The use of colors is optional

BOUNDARIES, MARKS, AND MONUMENTS

National, State or Province line

County line

Civil township, district precinct, or barrio

Reservation line

Land-grant line

City, village, or borough

Cemetery, small park, etc.

Township, section, and quarter-section lines (any one for township line alone, any two for township and section lines)

Township and section corners recovered

Boundary monument

Triangulation point or primary-traverse station △

Permanent bench mark (and elevation) BM × 1232

Supplementary bench mark (and elevation) × 1232

U. S. mineral or location monument ▲

Observation spot (astronomic position) ⊕

Any located station or object (with explanatory note) ⊙

MISCELLANEOUS

Rock outcrop

Stone

Gravel

Chert fragments

Made land

Sand spots

STANDARD SYMBOLS FOR USE ON SOIL MAPS

WORKS AND STRUCTURES

Roads
- Good motor
- Poor motor or private

Trails
- Good pack 3
- Poor pack or foot 4

Foot-traverse line

Power-transmission line

Fences
- Stone
- Worm
- Wire Barbed Smooth

Vacant house

Gravel pits
- Small
- Large GR. PIT

BOUNDARIES, MARKS, AND MONUMENTS

Survey corners
- Not found
- Not positively identified
- Positively identified

Tie points (points common to adjoining field sheets) A A1

Location where soil sample was obtained S

DRAINAGE

Intermittent stream
(crossable with heavy farm machinery)

Intermittent stream
(not crossable with heavy farm machinery)

Falls

Wet spot

RELIEF

Bedrock escarpment

Sink holes and small depressions

Easy to cultivate across
- Small
- Large

Very difficult or impossible to cultivate across
- Small
- Large

Containing water most of time
- Shallow
- Deep

OPTIONAL AND SPECIAL SYMBOLS
FOR USE ON FIELD SHEETS

ABCDEFGHIJKLMNOPQRSTUVWXYZ&

abcdefghijklmnopqrstuvwxyz

1 2 3 4 5 6 7 8 9 0

ABCDEFGHIJKLMNOPQRSTUVWXYZ&

abcdefghijklmnopqrstuvwxyz

1 2 3 4 5 6 7 8 9 0

Names of natural land features, vertical lettering
Names of water features, slanting lettering

STYLES OF LETTERING FOR USE ON FIELD SHEETS

CIVIL DIVISIONS

States, Counties, Townships, Land Grants, Reservations, Capitals, Cities, Towns, Villages, Localities.

ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz 1234567890

HYDROGRAPHY

Oceans, Seas, Gulfs, Bays, Lakes, Ponds, Rivers, Creeks, Brooks, Springs, Falls, Rapids, Marshes, Glaciers.

ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz 1234567890

HYPSOGRAPHY

Mountains, Peaks, Valleys, Plateaus, Plains, Cliffs, Canyons, Peninsulas, Islands, Capes.

ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz 1234567890

PUBLIC WORKS

Railroads, Canals, Tunnels, Mines, Bridges, Ferries, Highways, Trails, Fords, Dams, Parks, Cemeteries, Forts, Institutions.

ABCDEFGHIJKLMNOPQRSTUVWXYZ 1234567890

MISCELLANEOUS

Soil Symbols, Section Numbers.

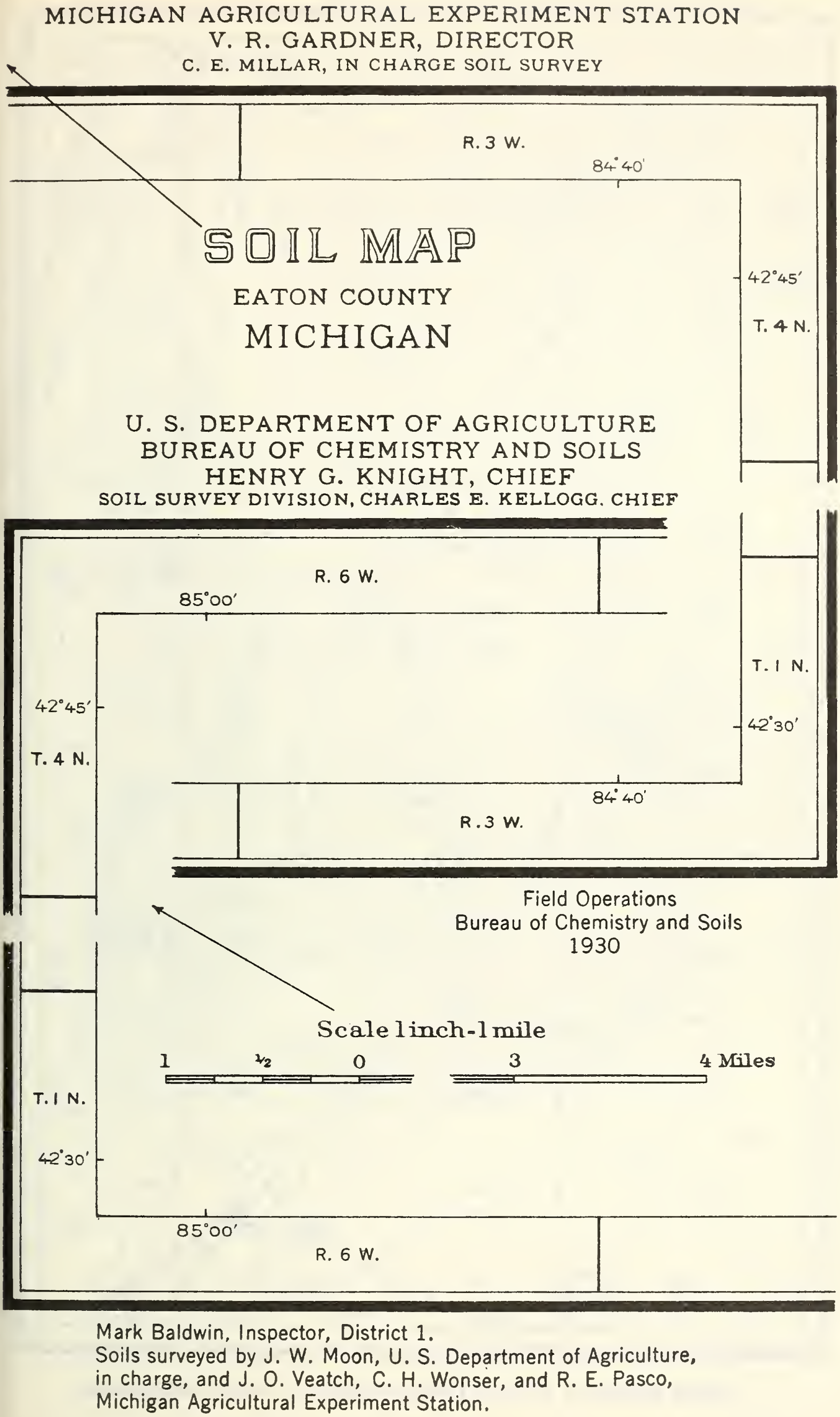
ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz 1 2 3 4 5 6 7 8 9 0

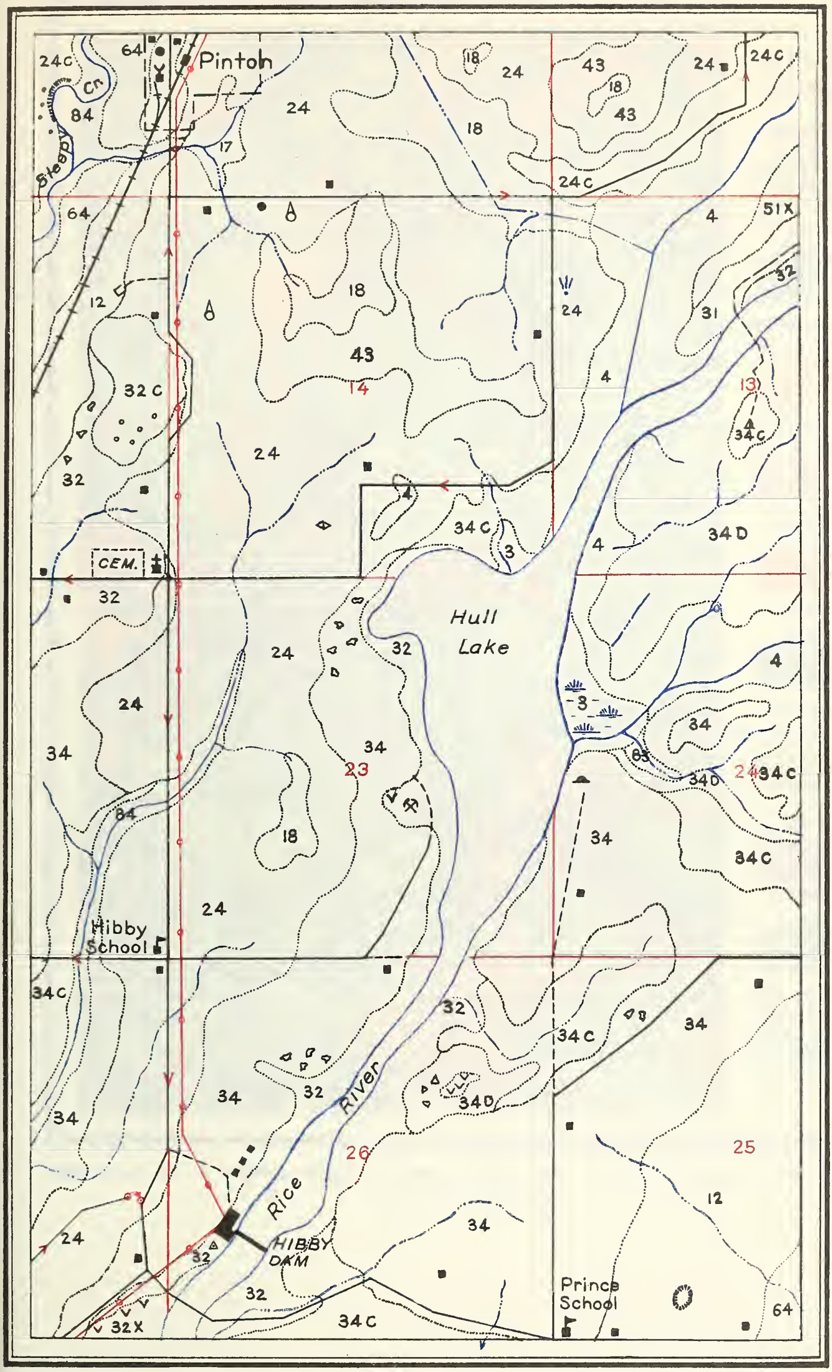
Note. ***The proportion of Small Letters is $\frac{2}{3}$ the height of the capital letter beginning the word.***

Thickness of letter $\frac{1}{7}$ of height. Slope 3 parts of base to 8 of height.

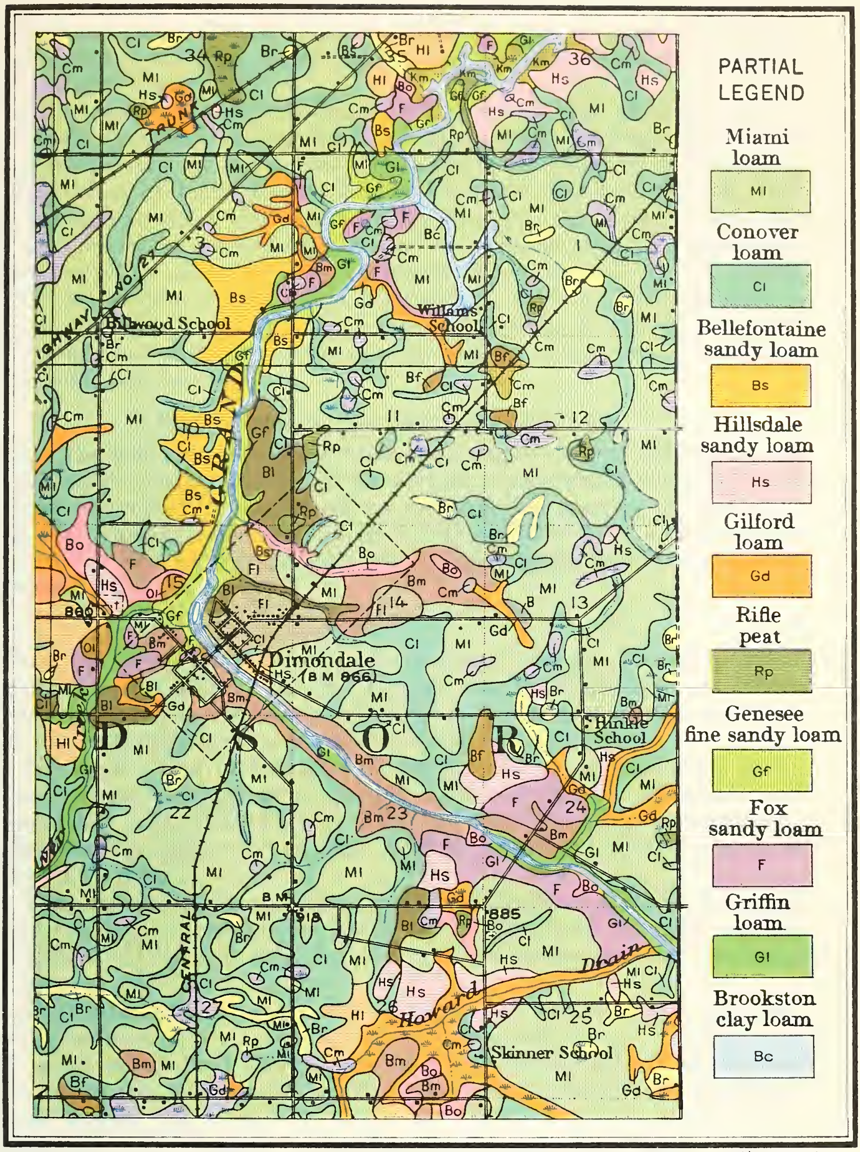
STYLES OF LETTERING FOR USE ON PUBLISHED SOIL MAPS



MARGINAL LETTERING FOR SOIL MAPS



REPRODUCTION OF SMALL SECTION OF A FIELD SHEET



Lith. A. Hoen & Co.

REPRINT OF A SMALL SECTION OF A TYPICAL DETAILED SOIL MAP (EATON COUNTY, MICH.)

can be examined. But care must be taken that no special features induced through tillage or recent changes in vegetation are confused with natural features.

Having selected a representative place for a type description, an excavation must be made extending through the solum and into the parent material. It is necessary that the excavation be rectangular, in order that at least one wall may be made vertical, smooth, and wide enough to show the entire profile clearly. It is important that this wall be as uniformly illuminated as possible and the excavation large enough to allow an easy examination of the soil in full depth. With soils having a noticeable microrelief, such as Podzols with a well-developed ortstein and the Solonetz complex, it will be necessary that a trench of considerable length be dug, in order that an accurate description can be made.

DESCRIPTION OF THE NATURAL LANDSCAPE

Since the soil represents the sum total expression of all the forces composing its environment, with each soil profile there are associated external characteristics as well as internal morphological features. Thus, the complete description of a soil must include a description of the relief, drainage, stoniness, native vegetation,[10] and any special features of the landscape.

RELIEF

From the point of view of soil genesis, there are four important general types of relief. Each of these has modifications and there are intermediate or gradational subtypes, but first of all the surveyor must understand these four principal concepts.

1. **Normal.**—The undulating to gently rolling upland with good, but not excessive, external drainage. The normal (or regional) soil is associated with this class of relief. Under the native vegetation, erosion may be said to be normal, or that associated with the genesis of the normal soil.

2. **Flat upland.**—Nearly flat upland with slow external drainage. Under the native vegetation, there is less than the normal erosion.

3. **Hilly.**—Hills and hilly upland with excessive external drainage and more erosion than normal.

4. **Flat lowland.**—Nearly flat or depressed lowland with poor external drainage, high water table, and no erosion.

In addition to the general class of relief, the length of slopes and their curvature, concave or convex, give rise to important modifications in soils.

Except for very sandy, gravelly, or otherwise exceptional parent materials, at least four distinct profiles can be expected from the same parent material on these four primary types of relief. In some instances important modifications or transitional types may need to be recognized. From parent materials of average chemical and physical composition the normal profile can be expected on the first, or normal, relief. Especially in the general region of the Pedalfers, soils having a compact or cemented B horizon and a deep, unusually eluviated A horizon are to be found on the second, or flat upland, relief where erosion has been insufficient for normal soil

[10] Obviously the climate must also be included, but the necessary observations are not and cannot be made in the course of a soil survey.

development. Soils with solums less well developed and thinner than the normal are to be found on the third type of relief, or hilly upland, due to the greater run-off and reduced amount of water available for plant growth, and to greater than normal erosion. Poorly drained intrazonal soils are to be found on the fourth type of relief, or flat lowland. In the humid regions, Wiesenboden (meadow soils), Bog, and Half-Bog soils may be expected, whereas the Solonchak, Solonetz, and Soloth soils may develop on such relief in the arid regions.

Many soils, especially intrazonal soils found on the flat lowland relief, exhibit local unevenness on the surface, in the form of shallow mounds or pits, a few (from about 2 to 20) feet in circumference and a few (from about 6 to 30) inches in height or depth. Such surface configurations are expressions of what is called microrelief and may be produced from a variety of causes. For example, the microrelief characteristic of the Ground-Water Podzol is due to the falling and upturning of shallow-rooted trees. The differential erosion of the solodized-Solonetz complex frequently produces a characteristic microrelief. The alternate shrinking and swelling of extremely heavy clay soils may produce a different type of microrelief. Such conditions must be described in connection with the definition of the soil type.

The slope cannot be well defined in terms of percentage alone, but attention must also be given to the length of slope and its uniformity. A series of comparative terms in common use are flat, undulating, gently rolling, rolling, strongly rolling, hilly, and mountainous, with such additional modifiers as choppy or broken. These terms are comparative only, and it is impossible and undesirable to attempt complete standardization for the entire country. In sections having well-defined relief, land commonly called rolling might have much more actual slope than land called rolling in sections generally flat.

Certain soil types may have such a range in relief that important subdivisions, from the point of view of land use, must be recognized in mapping. The manner of defining mappable phases according to relief will be discussed later.

In addition to a description of relief and surface configuration, any important facts regarding soil erosion should be noted. The definition of erosion phases to be shown on the soil map will be explained later. The soil surveyor should distinguish between accelerated soil erosion brought about locally as a result of improper land use and the erosion normal for the particular landscape.

DRAINAGE

It is of utmost importance that drainage conditions be observed. These can be grouped into two general categories, external and internal, which are not mutually exclusive, however, as one may have an influence on the other. By external drainage reference is made to the freedom with which water can run off the surface of the land, whereas internal drainage refers to the ease with which water can percolate through the soil. External drainage is largely a matter of slope and dissection but not entirely so. On nearly flat relief, one soil with good internal drainage may be considered to have also good external drainage, whereas the same degree of slope

might be inadequate for good external drainage with another soil having poor internal drainage. Seepage areas on slopes may have poor drainage, even though there is considerable slope. With these exceptions, external drainage is closely related to relief and is expressed by a series of analogous comparative terms as poor, slow, good, free, and excessive. These same comparative terms may be used for describing internal drainage. With many soils, such as the sandy Half-Bog, for example, the internal drainage would be free or excessive if the water table were lowered, but external drainage is poor. Such a condition should be so described. With soils having poor or slow external drainage the soil description should indicate, as closely as possible, the probable internal drainage of the soil if the water table were artificially lowered or the land tiled or ditched.

STONINESS

Many times the capabilities of soils for use will be determined, in part, by the degree of stoniness. Occasionally, it is necessary to establish phases to be shown on the map, either as areas or by symbols, as explained later. Not only is the degree of stoniness important, but also the character of the stones, especially their size. If the stones are loose and can be removed, the stoniness may be indicated as (1) free (no stones) or few, (2) common, (3) plentiful, and (4) very stony, corresponding to approximately 0 to 2 cubic yards, 2 to 20, 20 to 50, and over 50, per acre, respectively. Where the stoniness is due to large stones or small outcrops the conditions are described, especially bearing in mind their importance in land use. Whether the stones are more or less uniformly distributed over the area or concentrated in small patches is important.

NATIVE-PLANT ASSOCIATIONS

Wherever possible the native vegetation should be described. It is not necessary that every species be determined, but it is important that the general plant associations be noted, such as plains grassland, prairie grassland, desert shrub, oak-hickory, oak-pine, and spruce-fir. From the evidence available where the examinations of the soil are made, the dominant species and the associated species should be listed separately in the approximate order of their importance in the mixture. Common plant names can be used, except where such terminology is too indefinite. Especially where surveys include important areas of grazing or forest land, the soil surveyor will need to familiarize himself with both the common and scientific names of the principal plant species. In such areas, special attention must be given to the native vegetation in the soil-survey report and a list of the plants included with both their common and scientific names. These plant identifications must be checked carefully by a competent taxonomist, either in the field or from collected specimens. In grassland areas a soil surveyor will usually find it convenient to arrange a collection of the principal species at the field headquarters. Having these identified, subsequent checks can be made easily. Discarded magazines of large size may be used for such a collection. The specimens may be placed between the leaves and their names written on the margins of the adjacent pages.

The characteristics of growth and use of the native plants must be described in the report, where such plants are important. In the grazing land, the seasonal growth, rate and volume of growth, and palatability of the various species in respect to different grazing animals are of great importance. The presence of any poisonous plants is, of course, an important matter in grazing areas. In forested areas, information regarding rate of growth and uses of the native trees must be included.

The soil surveyor must make careful observations regarding the ecology of plants and especially the relationships between plant associations and soil types. This is an extremely important matter as regards both native and crop plants. Ordinarily there is a significant relationship between native plants and soil types, due to the great influence each has in the development of the other, yet the soil surveyor must be constantly on his guard not to ascribe differences in vegetation, due to overgrazing, forest fires, or other activities, to soil differences. Differences in humidity and other factors concerned in plant growth may cause variations in plant associations that are not directly dependent on soil differences. Further, it must be remembered that the ecology of crop plants is not identical with that of native plants, and soil differences of importance to one group may be less important to the other. Physical features of the land, such as small differences in slope or stoniness, that are apparently insignificant ecologically, may be very important because of their relationship to tillage and other techniques employed in using the land for crop plants.

DESCRIPTION OF THE SOIL PROFILE

The soil is made up of several layers, or horizons, called collectively, the soil profile. In making a type description, each of the horizons, including the parent material, must be carefully described as to thickness and properties.

THE PARENT MATERIAL

The parent material refers always to the unconsolidated mass from which the soil profile develops. It should never be confused with the bedrock from which parent material is produced through weathering. In general, these materials can be divided into three classes: (1) Those formed in place through disintegration and decomposition of the country rock, (2) those that have been transported from the place of their origin and redeposited before they became subject to modification by soil-building forces, and (3) organic deposits.

The principal subdivisions of these classes are suggested in the following outline.

1. Materials produced by the weathering of hard rocks in place. These are distinguished according to the nature of the original rocks, but the material must be fully described, since different parent materials may be produced from similar rocks. As much useful information concerning the mineralogical composition, hardness, structure, and other characteristics of the rock should be added as can be obtained. Frequently the soil surveyor can obtain considerable information from geological surveys.

A. Materials weathered from igneous rocks, such as:
   (1) Granite.
   (2) Syenite.
   (3) Basalt.
   (4) Andesite.
   (5) Diabase.
   (6) Rhyolite.

B. Materials derived from sedimentary rocks, such as:
   (1) Limestone.
   (2) Sandstone.
   (3) Shale.
   (4) Conglomerate.

(There are many varieties of each of these, many intermediate types, and in many places they occur closely interbedded.)

C. Materials developed from metamorphic rocks, such as:
   (1) Gneiss.
   (2) Schist.
   (3) Slate.
   (4) Marble.
   (5) Quartzite.
   (6) Breccia.
   (7) Phyllite.

2. Materials which have been moved from the place of their origin and redeposited during the weathering process itself or during some phase of that process and consist of, or are weathered from, unconsolidated formations. The principal groups of these materials are distinguished according to the nature of the main force responsible for their redeposition.

A. Those moved and redeposited by water:
   (1) Alluvium:
      (*a*) Local, as at the bases of slopes.[11]
      (*b*) General, as along stream courses
   (2) Lacustrine deposits.
   (3) Marine sediments.
   (5) Beach deposits.

B. Those moved and redeposited by wind:
   (1) Loess.
   (2) Dune sands.
   (3) Wind drifts.

C. Those moved and redeposited by glacial activity:
   (1) Glacial till (deposits of glacial till may be found in ground moraines, terminal moraines, etc.).
   (2) Fluvioglacial deposits:
      (*a*) Outwash materials.
      (*b*) Eskers and kames.

D. Those moved and redeposited by gravity (colluvial): Talus.

[11] Such local alluvium should not be called colluvium or colluvial material. These terms are to be applied to material transported primarily by gravity and not to that moved primarily by water, regardless of the slope.

3. Organic materials (these must be described as to color, texture, compactness, and other characteristics):
   - A. Woody peat.
   - B. Fibrous peat.
   - C. Moss peat.
   - D. Sedimentary peat.
   - E. Colloidal peat.
   - F. Muck.
   - G. Diatomaceous deposits.

The parent material should be described as to mechanical and lithological composition, mode of origin, where that can be determined, and stratification. Of particular importance is the hardness of the formation and whether or not the parent material has developed from hard rocks in place or from unconsolidated materials. The hardness or induration of the material directly beneath the solum is especially important. Of particular importance also is the stratification of the parent material. Great care must always be taken to determine as nearly as possible whether or not the solum or any particular horizon of the profile is developed from material similar to that found in the substratum. In some instances it is obvious that the solum has developed from stratified material, and it is very difficult to be sure of the exact character of the original material from which the soil horizons have developed. As a matter of fact, it is frequently impossible to be absolutely certain that the solum has developed from the geological material directly underneath, no matter how much that appears to be so.

Care should be taken to determine the depth of soil, or of soil and unconsolidated parent material, over hard rock where such formations lie near the surface. The capability for use of many soil types and phases of soil types is greatly influenced by this feature.

ORGANIC MATTER AND ROOT DISTRIBUTION

The content of organic matter is one of the most important characteristics of the soil. Two general forms of soil organic matter are recognized: (1) that which is undecomposed or only partly decomposed, and (2) that which is well decomposed. In addition, the living organic matter of the plant roots might be considered a third class. The first form is often referred to as organic residue or raw humus, and it constitutes the main bulk of the organic matter in forested soils. The second form, commonly known as humus, predominates in the grassland soils. The upper layers (A_0 and A_{00}) of the forested soil are almost entirely made up of organic matter and rest on the solum. Thus, the organic matter lying on the solum must not be confused with that in the solum itself mixed with the mineral portion. The organic matter of the first class should be described as to color, texture, degree of decomposition, and thickness. Where the plant remnants are distinguishable, the source of the material should be noted. The residues may be made up of the needles of coniferous trees, leaves of deciduous trees, mosses, grasses, or other plant remains.

The relative content of humus in the horizons of the solum is indicated generally by the color of the soil. Black soils are usually high in this constituent, and progressively lighter colored soils contain, generally, lower amounts. It must be remembered, however, that other compounds in the soil which influence color vary independently of the organic matter. If black well-dispersed organic colloids are so distributed as to coat each individual grain, a comparatively small total amount may impart a very dark color to the soil. With increases of annual temperature, other things being equal, it seems that normal upland soils having the same content of organic matter are lighter in color.

The general distribution of the humus in the solum should be described in association with the average thickness of the horizons containing humus, infiltration of humus into the deeper horizons, and other features.

The plant roots supply much of the material from which humus is formed. Therefore, it is important to note the general distribution of roots in the soil, especially where certain morphological features unfavorable to roots are present. Frequently, exceedingly dense or indurated horizons are more or less impenetrable to roots. Some other horizons are unfavorable to root development because of a high concentration of salts. Some soils have either stationary or fluctuating water tables which restrict root growth to certain horizons. A rather wide and important difference in the root development of perennial plants as compared to that of annual plants may be noted, especially in soils having fluctuating water tables.

All these conditions are important, especially in considering the soil as a medium for the growth of plants, and should be examined and described carefully. The depth at which most of the roots are distributed and the depth of their penetration into the lower soil layers should always be noted. In evaluating such information it must be remembered that plants vary a great deal among themselves in the effectiveness with which their root systems may be able to extend into different kinds of soil. The soil surveyor cannot depend entirely on the examination of a soil made at one time for determining the amenability of the soil to roots. As the hardness of a horizon may vary somewhat with the seasons and with such cultural practices as irrigation, during certain periods roots may penetrate a soil which appears very hard at other times.

DETERMINATION OF HORIZONS

The description of the soil profile consists of the descriptions of its several horizons. The soil horizons are genetically related to one another and are produced through the action of soil-building forces. They vary tremendously in different soils; many horizons that are well developed in some soils may be absent or only weakly developed in others. Figure 12 illustrates the general or hypothetical soil profile. Like the hypothetical plant used by a botanist to illustrate possible forms, no such entity exists in nature but merely serves to illustrate the possible horizons. No one soil has all the horizons well developed, but every soil has at least a part of them.

Organic debris lodged on the soil; usually absent on soils developed by grasses.

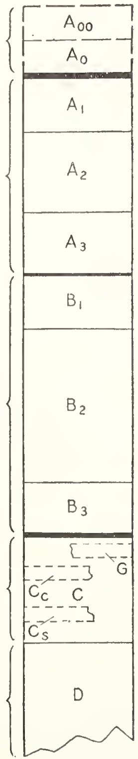
The solum. (This portion includes the true soil, developed by soil-building processes.)

Zone of eluviation

Zone of illuviation. (Exclusive of carbonates or sulphates, as in Chernozem, Brown soils, and Sierozem. In such soils this horizon is to be considered as essentially transitional between A and C.)

The weathered parent material. Occasionally absent, i. e., soil building may follow weathering so closely that no weathered material that is not included in the solum is found between B and D. Horizons lettered C_c and C_s represent possible layers of accumulated calcium carbonate or calcium sulphate found in Chernozem and other soils.

Any stratum underneath the soil, such as hard rock or a layer of clay or sand, that is not parent material but which may have significance to the overlying soil.



A_{00} — Loose leaves and organic debris, largely undecomposed.

A_0 — Organic debris partly decomposed or matted; frequently divided into subhorizons.

A_1 — A dark-colored horizon, containing a relatively high content of organic matter, but mixed with mineral matter. Thick in Chernozem and very thin in Podzol.

A_2 — A light-colored horizon, representing the region of maximum leaching (or reduction) where podzolized or solodized. The bleicherde of the Podzol. Absent in Chernozem, Brown soils, Sierozem, and some others.

A_3 — Transitional to B, but more like A than B. Sometimes absent.

B_1 — Transitional to B, but more like B than A. Sometimes absent.

B_2 — A deeper colored (usually) horizon representing the region of maximum illuviation where podzolized or solodized. The ortstein of the Podzol and the claypan of the solodized Solonetz. In Chernozem, Brown soils, and Sierozem this region has definite structural character, frequently prismatic, but may not have much if any illuviated materials and represents a transition between A and C. Frequently absent in the intrazonal soils of the humid regions.

B_3 — Transitional to C.

G represents the glei layer of the intrazonal soils of the humid region.

D — Underlying stratum.

NOTE.—Important subdivisions of the main horizons are conveniently indicated by extra numerals, thus: A_{21} and A_{22} represent subhorizons within A_2.

FIGURE 12.—A hypothetical soil profile having all the principal horizons. It will be noted that horizon B may or may not have an accumulation of clay. Horizons designated as C_c and G may, and usually do, appear between B_3 and C.

The principal horizons of the soil profile are designated as A, B, and C. Taken together, the A and B horizons are referred to as the solum which represents the true soil, produced by soil-building processes from weathered materials and in which the biological activities take place. The designation C refers to the parent material or unconsolidated weathered rock directly under the solum.[12]

The diagram in figure 12 shows the principal soil horizons in their genetic positions in respect to one another, and their nomenclature. This system of nomenclature allows each horizon to be lettered according to its genetic position and at the same time allows expansion for subhorizons or transitional horizons in very detailed studies. Thus the letters A, B, C, and D, as used in descriptions of the soil profile, designate more than a simple sequence of different horizons, and they should not be used unless they can be used with reasonable certainty. Especially with young soils, laboratory investigations frequently are required, in order to use the correct nomenclature with certainty. It is not at all necessary that the soil surveyor use the letters, and in all instances of doubt the horizons should be numbered simply 1, 2, 3, * * * from the top, and if the genetic nature of any of them can be recognized positively, this can be indicated by the corresponding symbol in parentheses, as 1 (A), 2 (A_2), 3, 4 (B_2) * * * Where the letters are used they should be used according to a definite system, and horizons within the solum should never be indicated simply as A_1, A_2, A_3, A_4, * * * or B_1, B_2, B_3, B_4, * * * indiscriminately. For example, soils are frequently found in which B_1 is either very thin or absent. In such instances the designation B_1 should not be used in place of the designation B_2 for the main portion of the B horizon. Similarly A_3 or B_3 may be absent. Sometimes C is absent, that is, soil formation may follow weathering so rapidly that there is no material above the rock which is not part of the solum.

Subhorizons within C, the parent material, may be shown as C_1, C_2, * * *. Prominent layers or formations underneath the parent material are better indicated as D than as subhorizons of C. The horizons shown in the diagram as C_c, C_s, and G usually occur just at the top of C. These should be labeled as such, rather than as subhorizons of either B or C. In the field it is not always easy to distinguish the limits of C_c and C_s; they may almost overlap or they may be separated. Again, it must be stressed that, although the letters indicating the genetic positions of the horizons may be better than simple numbers where correctly used, simple numbering in consecutive order is very much better than incorrectly used letters.

All measurements of the depths of horizons should be made with the top of the A_1 horizon as 0. In instances of those soils having A_0 and A_{00} horizons lying on the A_1, these should be measured upward from the top of A_1. If profile descriptions should be reported with

[12] Originally the A horizon was considered to include the upper part of the solum, in which the accumulation of organic matter (and plant nutrients) was taking place through the direct influence of plants, as in the surface soil of the Chernozem; and the B horizon included the lower part of the solum, transitional between the more or less uniformly developed A horizon and the parent material, unaltered by soil-building processes. The study of soils was later extended to those having a leached layer in the upper part of the solum and a horizon of colloidal accumulation in the lower part. Thus the A as now defined may include a horizon (A_2) impoverished of colloids and bases through such a process as podzolization; and the B in such soils may be characterized by a higher content of colloid.

measurements from the surface of A_0 or A_{00}, it would be very difficult to make comparisons with other soils, since the thickness of these layers is so dependent on the frequency and intensity of forest fires, grazing, and similar outside influences. Although horizons A_0 and A_{00} rest on the solum, they are nevertheless an important part of the whole soil, especially from the point of view of soil genesis.

The average depth of each horizon should be noted, as well as the approximate limits. In some soils the separate horizons stand out rather conspicuously, whereas in other soils each merges into the other through gradational zones of some thickness. By simple inspection of the profile in place it is sometimes difficult to determine the exact position of the boundary. Small samples must be removed and compared side by side, in order to locate the gradational area and determine the limits of the horizons. As each boundary is located, small markers can be used until all the horizons have been located, after which the measurements can be made and recorded. The profile description should include a note regarding the character of the boundary, that is, whether it is abrupt, gradual, diffused, smooth, wavy, or broken. In many instances, especially with soils having a pronounced microrelief, a trench must be dug and the horizons sketched to scale for some distance laterally, in order that a true picture of the complex profile may be recorded. For special studies of such soils it may be convenient to set stakes, at intervals ranging from about 6 to 12 inches, at the margin of the trench for reference in measuring the horizons. Using one stake as a beginning point, the elevations of the others in reference to this one can be obtained easily by the use of a Y-level.

Especially for detailed studies of soil profiles, various systems of abbreviated nomenclature have been proposed by several investigators. The soil surveyor may find it convenient to adapt some such system to his needs, but at present no particular one of them is recommended. In figure 13 is reproduced a sheet removed from a fieldman's notebook, carrying a comparatively brief but adequate profile description.

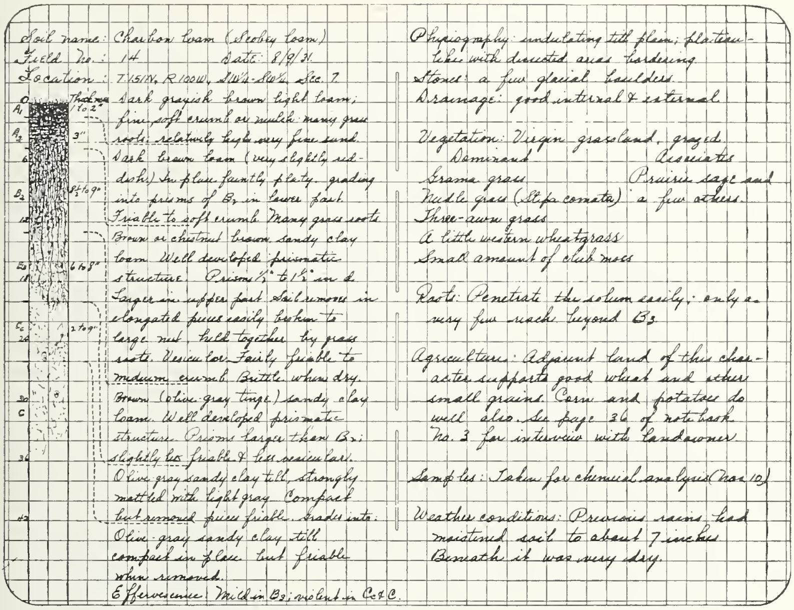
Each horizon of the soil profile, including the parent material, must be described as to texture, structure, porosity, consistence, and color.

TEXTURE

The texture of soils refers to the relative size of the individual grains. On the basis of the relative percentages of different-sized particles (separates), the textural soil classes are recognized. The principal classes, in order of the content of the finer separates, are as follows: Sand, loamy sand, sandy loam, loam, silt loam, clay loam, and clay. In addition there are recognized others with modifying adjectives, according to the relative size of the coarser particles, such as fine sand, loamy fine sand, fine sandy loam, very fine sandy loam, coarse sandy loam, gravelly sandy loam, gravelly loam, and cobbly loam. Variations within the clay and clay loam classes are indicated as sandy clay, stony clay, silty clay, sandy clay loam, and silty clay loam. Where the content of stones in a given soil type is sufficient to influence its utilization significantly and is general in the occurrence of the type, such textural names as stony loam, stony sandy loam, and stony sand may be recognized. Where the content of stone varies,

apart from the other characteristics of the soil type, their presence is indicated by phase designations defined in a way to indicate the degree of stoniness. The manner of defining and indicating such phases on the soil map is discussed later.

The texture of the soil is determined in the field by feeling with the fingers. Considerable skill and experience is required for consistent and accurate determinations, and each chief of party must check the determinations of the members of his party at frequent intervals. Care must be taken not to confuse small aggregates of the fine separates with sand. Frequently clay particles are grouped into small hard aggregates, giving the soil a feel of silt or sand, especially when dry. Again a small content of clay, humus, or other


Soil name: Charbon loam (Scobey loam)
Field No.: 14 Date: 8/9/31.
Location: T.151N, R100W, SW¼-SW¼ Sec. 7.

A₁ (1 to 2"): Dark grayish brown light loam; fine, soft crumb or mulch. Many grass roots; relatively high very fine sand.
A₂ (3"), B₂ (8½ to 9"): Dark brown loam (very slightly reddish) In place faintly platy, grading into prisms of B₂ in lower part. Friable to soft crumb. Many grass roots.
B₃ (6 to 8"): Brown or chestnut brown sandy clay loam. Well developed prismatic structure. Prisms ½" to 1½" in d. Larger in upper part. Soil removes in elongated pieces easily broken to large nut, held together by grass roots. Vesicular. Fairly friable to medium crumb. Brittle when dry.
Cc (2 to 9"): Brown (olive-gray tinge) sandy clay loam. Well developed prismatic structure. Prisms larger than B₃; slightly less friable & less vesicular.
C: Olive-gray sandy clay till, strongly mottled with light gray. Compact but removed pieces friable. Grades into:
Olive-gray sandy clay till compact in place but friable when removed.
Effervescence: Mild in B₃; violent in Cc & C.

Physiography: undulating till plain; plateau-like with dissected areas bordering.
Stones: a few glacial boulders.
Drainage: good internal & external.

Vegetation: Virgin grassland, grazed.

Dominant	Associates
Grama grass	Prairie sage and
Needle grass (Stipa comata)	a few others.
Three-awn grass	
A little western wheatgrass	
Small amount of club moss	

Roots: Penetrate the solum easily; only a very few reach beyond B₃.

Agriculture: Adjacent land of this character supports good wheat and other small grains. Corn and potatoes do well also. See page 36 of notebook No. 3 for interview with landowner.

Samples: Taken for chemical analysis (Nos. 10)

Weather conditions: Previous rains had moistened soil to about 7 inches. Beneath it was very dry.

FIGURE 13.—Copy of typical profile description from a fieldman's notebook. Other forms may be used for taking the necessary notes, some of which are more elaborate and allow the inclusion of more detail by the use of symbols. The type of description shown on this sheet is adequate for ordinary purposes in soil survey work.

cementing materials may give a soil such hardness or compactness in place as to suggest a much higher content of clay than actually is present. The soil must be moistened and worked between the fingers, in order to avoid such mistakes.

It is always difficult to determine soil texture accurately at extremes in soil structure. Although every effort should be made for an accurate estimation of texture, fortunately small differences are of less importance at such extremes in structure than under ordinary conditions where the soil is more or less friable.

Exact determinations of texture are made on samples in the laboratory by mechanical analyses, and against these data the fieldman can check his judgment. When the textural class names were first suggested, definitions in terms of the relative percentage of the several soil separates were made. Recent researches have shown that

the older points of separation were not well chosen and that the older methods of mechanical analyses did not fully disperse the finer separates. At present no exact definition of the textural classes in terms of figures applicable to all the great soil groups can be given. Further research on mechanical analyses is being done, especially in respect to the clay portion, in order that factors may be developed for correlating the laboratory results precisely with the field results.

STRUCTURE

Soil structure refers to the manner in which the individual soil grains are arranged. Its importance in soil classification and as a determinant of soil productivity can scarcely be overemphasized. The capability of any soil for the growth of plants depends as much on the physical condition or structure of the soil as it does on fertility (in a chemical sense). Although there are no precise "single-value" expressions for soil structure in the field, there are several fairly well established morphological types of structure which vary in themselves as regards hardness and consistence. Soil has a structural form in place, such as prismatic, columnar, nutlike, platy, granular, crumb, or fragmental. When removed, the larger aggregates may fall easily into smaller aggregates, such as prisms into nutlike aggregates. Under different degrees of pressure in the hand, these forms may be broken down into still smaller aggregates, such as crumb, granular, or single grain. The hardness of the aggregates and the ease with which they can be crushed is extremely variable. For example, soils may have a hard, medium, or soft nutlike structure or a hard, medium, or soft granular structure. The granular or nutlike aggregates may be angular, subangular, or rounded. Some of the more important types with common modifications are listed as follows:

Prismatic.—Blocky structure with the vertical axis longer than the horizontal, as in the B horizon of many Chestnut soils.

Nutlike.—Blocky structure, angular as in the B horizon of the Gray-Brown Podzolic soils, or rounded as in the B horizon of many Chernozems.

Columnar.—Prismatic with rounded tops, as in the B horizon of the solodized-Solonetz.

Platy.—Thin horizontal plates, as in the A_2 horizons of the Podzol and the solodized-Solonetz.

Crumb.—Generally soft, small, porous aggregates, irregular in shape, as in the A_1 horizons of many soils.

Granular.—Hard or soft, but firm, small aggregates, angular or rounded, as in the A horizon of many Chernozems.

Fragmental.—Hard or soft, but firm, irregular aggregates, angular or subangular, as in many young soils developed from silty or clayey alluvium.

Phylliform.—Thin layers, less distinct and thinner than platy. (Where this condition is confined to inherited layers, as in the C horizon of soils developed from thin-bedded sediments, the term "laminated" should be used.)

To indicate a lack of definite structure, the following terms are normally used:

Single grain.—Each grain by itself, as in dune sand (structureless).

Massive.—Large uniform masses of cohesive soil, sometimes with irregular cleavage, as in the C horizons of many heavy clay soils (structureless).

Some investigators use many additional terms for describing soil structure, and in the literature there may be all sorts of expressions used, many of which are poorly defined, if indeed they are defined at all. A large portion of them are used partly in reference to soil structure and, at the same time, partly in reference to soil consistence or porosity and thus cannot be applied to any of the three. Unless some special condition is met with, the terms already given are adequate. Other terms should not be used unless they are properly defined and refer specifically to soil structure. Soil science has not advanced to the stage where it is possible or even desirable to obtain complete standardization of terminology, but loose or bizarre terms should be avoided. A small number of terms, appropriately modified as to size and quality of the aggregates, makes possible more comparable descriptions than a large number of overlapping terms.

Each structural type should be modified appropriately so that the hardness, size, friability, and other characteristics of the aggregates are clearly defined. The approximate size should be given of prismatic, columnar, nutlike, and granular aggregates.

The principal description of a soil should be made when it is at its normal moisture content, but attention should be called to any striking contrasts in structure under other moisture conditions to which the soil is subject. For example, a well-developed prismatic structure may not be easily recognized under extreme moistening. The soil surveyor must study the same soils under different moisture conditions and note the changes which take place, in order that he may not be misled when examining soils that are abnormally wet or extremely dry.

SPECIAL FORMATIONS

By special formations in the soil, reference is made to (1) local concentrations and segregations of various compounds and concretions, (2) local efflorescence of salts, and (3) incidental morphological features produced by the activity of insects, worms, and rodents, and by roots.

Concretions.—Concretions refer to local concentrations of certain chemical compounds which form grains or nodules of various sizes, shapes, and colors. These may be hard or soft, irregular or rounded (shot). As examples may be mentioned the lime concretions in Chernozem and the iron concretions of many Podzols and Laterites. Manganese, and sometimes considerable phosphorus, may be present in such bodies. Wherever they are found, the soil description should indicate their color, size, shape, and durability, and their amount and distribution in the soil horizons.

Ortstein.—Ortstein is hard, irregularly cemented sandy material, such as that found in the B horizons of sandy Podzols, especially the Ground-Water Podzols. It may exist as rather small isolated grains, as large irregular lumps, or in thick solid crusts.

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Efflorescence.—Efflorescence of salts refers to the occurrence of various salts in crystalline form. Among these the efflorescence of lime is of the most common occurrence. Lime carbonate occurs in various forms in soil. It may be uniformly distributed through the mass or in several concentrated forms, as pseudomycelium, representing thin, irregular veins thoroughly penetrating the soil mass (usually along thin tubular pores), as nodules or nests (sometimes referred to as "white eyes"), and as films on the walls of cracks. Crystals of gypsum are not infrequently found in nests or nodules. These and other salts may occur as concentrations at the surface in crusts or at some depth within the soil. The depth of occurrence, degree of concentration, and forms of efflorescence should be carefully studied and described.

Krotovinas.—Krotovinas refer to irregular tubular streaks within one horizon of material transported from another horizon. They are caused by the filling of channels made by rodents with material from outside the horizon. In the soil profile they appear as rounded or elliptical spots of various sizes. They may have a light color in dark horizons or a dark color in light horizons, and their other qualities of texture and structure may be unlike those of the main body of soil in the horizon of their occurrence.

POROSITY

Soil porosity refers to the pore space or cavities in the soil mass. It is an important characteristic, because these cavities form the channels for the circulation of gases and solutions through the soil. The total porosity, as expressed in percentage of the soil mass, cannot be determined in the field. The field description, however, should include some notes regarding any observable features of porosity. Not infrequently the soil material is perforated by numerous small and irregular tubular pores; again it may be fractured by intersecting fissures; or it may be penetrated by channels dug by insects, worms, or small rodents. These conditions often have a definite relation to the distribution of roots, which must be noted in the field descriptions. Again they may have a particular significance in the distribution of precipitates from soil solutions and suspensions. The walls of cavities often are somewhat glossy and have a rather dark color which may indicate an illuviation of certain colloids, either organic or inorganic. It must be remembered that soil porosity is subject to considerable change with differences in moisture. The apparent porosity of many heavy soils usually is greatly increased during periods of drought, because of cracking, whereas the porosity of the same soils may be reduced greatly if the soil is saturated by water. Therefore, the principal definition of porosity must be made when the soil is in its normal moisture condition.

CONSISTENCE

Soil consistence refers to the relative attraction (cohesion and plasticity) of the particles in the whole soil mass for one another; whereas structure refers to the attraction and arrangement of soil particles within particular aggregates. Especially consistence refers to the different grades of compactness. The self-explanatory relative terms commonly used for defining soil consistence are: Loose or open;

slightly, moderately, or very compact; mellow; friable; crumbly; plastic; sticky; hard; and cemented. It must be remembered that soil consistence varies with different conditions of soil moisture. A soil may be sticky when sufficiently moist and either hard or crumbly when it is dry. Therefore, a description of any particular type of consistence must include a reference to the moisture conditions at the time of the observations and to any changes of consistence under different moisture conditions.

It is of particular importance to note any differences of consistence within the soil profile. Very often the consistence varies among the several horizons. For example, the consistence of the B horizons of many soils is more compact than that of either the A horizons or of the parent material. The consistence of the A and B horizons of the solum as a whole and of the parent material should be compared. Whenever such comparisons are made, care should be taken that all parts of the profile are under comparable moisture conditions.

COLOR

Color is the most obvious and one of the most significant characteristics of the soil. Each soil horizon has a distinctive color. Although color in itself may be of minor importance, it is frequently a significant criterion of other soil conditions of extreme importance. The content of organic matter in soil, for example, is a characteristic which is nearly always evidenced by soil color. Other factors being constant, soil colors may range from nearly white, through the browns or dark grays, to black, as the content of organic matter increases. The most stable part of the decomposed organic matter, humus, is darker than the raw, or less well decomposed, plant remains. Raw woody peat is usually brown, whereas the well-developed organic soil produced from such material is black or nearly so. It is further true that under high annual temperatures soils are not so dark as those of colder regions, provided the content of organic matter is the same. As organic matter is not the only coloring matter in soils, color by itself is not an exact measure of the content of this important constituent. There are instances where soils owe their dark color largely to compounds of manganese or to magnetite.

The red or reddish-brown colors of soils are greatly dependent on the content of unhydrated iron oxide. As this form of iron is relatively unstable in poorly drained soils, red colors usually indicate good drainage and good aeration. This is almost invariably true, for example, of the red soils of the Southern States. In some instances, however, the red color of the soil may be inherited from the parent rocks and is not due to soil-forming processes. This is especially true of soils developed over the "Red Beds" of Triassic and Permian formations.

The yellow color in soils is commonly due to hydrated iron oxide.[13] Many such soils are imperfectly drained or inherit their color from a previous condition of poor drainage. Frequently, well-drained sandy soils exhibit a yellow color which is brought about by a very

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[13] The degree of dispersion influences the color of precipitates of iron oxide, as well as the hydration. To what extent the degree of dispersion is important in determining the color of natural soil horizons is unknown to the writer.

small amount of organic matter and other coloring materials, such as the unhydrated iron oxide, mixed with a large percentage of nearly white sand.

Gray shades may be brought about in several ways. The compounds containing reduced iron are commonly gray or bluish gray. Thus the color of glei horizons of the poorly drained intrazonal soils of the humid region is gray. Especially where the water table fluctuates, imperfectly drained soils are frequently mottled with gray, yellow, and brown at some depth beneath the surface. Again, a gray color may indicate a very low content of organic matter and iron, as in the A_2 horizons of the Podzol. In the semiarid and arid regions, certain soil horizons, or even entire solums, may appear gray or nearly white as the result of a very high content of calcium carbonate or other salts. Nearly white soils may sometimes be found, especially in the humid regions, as an inheritance from the parent material. The failure of soils to accumulate organic matter ordinarily indicates an environment unfavorable to the growth of ordinary crop plants, and white soils are almost invariably unproductive.

Nearly every soil profile consists of several horizons differing in color. In every soil examined and described in the field the complete color profile should be presented. A horizon may be uniform in color or it may be streaked, spotted, variegated, or mottled in many ways. The appearance of the color pattern should be carefully studied and described. Local accumulations of lime or organic matter may produce a spotted appearance. Streaks or tongues of color may result from the seeping downward of colloids, organic matter, or iron compounds from overlying horizons. Conditions of imperfect drainage may produce a more or less distinct mottling. A variegated coloration often occurs in parent materials which are not completely weathered.

In a study of soil color it should be noted whether or not a color pattern has any relationship to the structure or porosity. Structural aggregates in the soil must be crushed to determine whether the color is uniform throughout the material of the horizon. In many instances it will be found that the black color of granules is due to a thin coating and that the basic color of the material is brown or yellow. When such granules are crushed, the resulting mass will be much lighter colored than the original surface. A red color may exist as a coating over structure particles or sand grains, and a gray color also may be due to a thin film of leached soil around a darker colored aggregate.

A marked change in color takes place in many soils on drying. It is generally agreed that any quantitative measurement of color in terms of physical standards must be made by observation of the air-dried sample. Soils in the field usually do not reach such a state of dryness, and it is necessary that the colors of soils in the field should be noted at some common stage of moisture, preferably at the stage of optimum moisture content. The official description of the color of a soil type should include that made from air-dry samples. The color in the field should be noted also, together with sufficient information regarding the moisture conditions of the soil.

The designation of soil color in the field consists of the principal color with modifiers for shades and depths of color. The principal soil colors are black, gray, brown, red, and yellow. These may be modified by the appropriate term from among the following: Grayish, brownish, reddish, yellowish, pinkish, purplish, bluish, or olive. Thus the term grayish brown is used where the principal color is brown, modified by gray; whereas the term brownish gray indicates a principal color of gray, modified by brown. The principal color, or its modifier according to shade, may be further modified by the terms light or dark. Occasionally the terms, dull and bright, may be added for further specificity, although their use is usually unnecessary. In this way the color of soil horizons may be designated as reddish brown, light olive gray, yellowish red, dark grayish yellow, black, purplish red, light gray, and so on.

The terminology employed in describing soil color should be confined to the terms just given unless some very special or unusual condition exists. Such expressions as mouse gray, lemon yellow, cream, tan, and leather brown should be avoided by all means. A few other terms, including ashy, olive drab, pale, whitish, rusty brown, and coffee brown, have been used in the literature and are permissible, but their use should be studiously avoided, as they are rarely, if ever, necessary for an adequate description. Without doubt, many soil descriptions, including several published by the writer, carry an excessive and unnecessary number of fine color distinctions.

A precise measurement of soil color in terms of strict physical standards can be made in the laboratory. This can be accomplished through duplication of the soil color by the rapid rotation of a wheel on which are exposed segments of disks of standard colors. The proportions of the segments are varied until the composite color exactly matches that of the soil. Four disks—black, white, red, and yellow—will reproduce essentially any soil color.

As an example, the analyses of the colors of several soils, according to physical standards, together with their soil color names, are given in table 1. These measurements were made according to the Munsell system, using the following standard color disks, neutral 9 (white), neutral 1 (black), red 4/9 (red), and yellow 8/8 (yellow).

TABLE 1.—*Several soil colors and their values according to the Munsell system*

Soil color name	White	Black	Yellow	Red	Soil color name	White	Black	Yellow	Red
	Percent	*Percent*	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*	*Percent*
Very light gray	73	10.5	10.5	6	Very dark grayish brown	8.5	81	5.5	5
Light gray	40	41	13	6	Black	4	94	1	1
Gray	25	61	9	5	Olive gray	15	63.5	15.5	6
Dark gray	18.5	68	7.5	6	Dark olive gray	16	69.5	10.5	4
Light grayish yellow	40	16	32.5	11.5	Olive yellow	10.5	44.5	29	16
Grayish yellow	23	38	28	11	Dark olive yellow	10.5	72	13.5	4
Yellow	11.5	19	45.5	24	Light reddish yellow	14	32.5	28.5	25
Grayish brown	15	50	22	13	Yellowish red	9	20	26	45
Yellowish brown	11	57.5	19.5	12	Red	5.5	27	20.5	47
Brown	10	52	21.5	16.5	Dark red	3	71.5	7.5	18
Light reddish brown	10	36	25.5	28.5	Dark brownish red	3.5	74.5	7	15
Reddish brown	6	50.5	18.5	25	Purplish brown	11.5	59	10.5	19
Dark brown	7	67	13.5	12.5	Purplish red	11	53	11	25
Dark grayish brown	7	79	9	5					
Very dark brown	8	79	7	6					

The color names used in the descriptions of soils are not in precise agreement with the scientific names. For example, the so-called red soils, which are universally known as red and which give the impression of red to the eye, are not found to be an unqualified red when subjected to color analysis or when compared with a standard chart of colors. Soils that appear bluish or greenish (olive) may be lacking in either blue or green. In describing soil color in the field and laboratory the commonly accepted names for soil colors should be used. Where quantitative color data are available, they may be appended.

REACTION

The soil surveyor should determine the presence of free carbonates in the soil and parent material by the use of dilute hydrochloric acid. The degree of effervescence may be noted as mild, moderate, or strong. When testing dry soils, care must be taken not to confuse the emission of air bubbles with slight effervescence. The soil horizons should be tested in several different places. Frequently soils will be found which do not contain free carbonates except in pieces of undecomposed limestone or in small accretions. The boundary between the upper part of the soil not containing free carbonates and that beneath, which effervesces with the acid, may be extremely irregular. Certain heavy clay soils with a hard, well-developed, columnar structure, for example, have been examined where effervescence occurred at a depth of a few inches from the top of the solum on the inside of the structural aggregate but only at much greater depths on the outside of the same aggregate because of the much greater leaching between the structural units. This boundary is very important and should be located carefully.

It is important that the approximate hydrogen-ion concentration be known for each of the principal soil horizons, especially of those soils in the group of Pedalfers. As heretofore pointed out, the ordinary field kits now available, which make use of various color indicators, may not give consistently satisfactory results with soils of high pH values. With these soils, as well as with others of an extreme character, such as very acid Podzols and Bog soils, dependable determinations can be made only in the laboratory. With the Pedalfers of the United States, the determination of pH between about 4.8 and 7.5 can ordinarily be made with fair accuracy in the field. In addition, the pH of samples of the horizons from the principal soil types of each area should be determined in a suitable laboratory with a hydrogen or glass electrode.

The following terms are used in order to describe the reaction of soils of known pH:

	pH
Extremely acid	Below 4.5
Very strongly acid	4.5–5.0
Strongly acid	5.1–5.5
Medium acid	5.6–6.0
Slightly acid	6.1–6.5
Neutral	6.6–7.3
Mildly alkaline	7.4–8.0
Strongly alkaline	8.1–9.0
Very strongly alkaline	9.1 and higher

PRESENT LAND USE

Having described the soil and associated features of the natural landscape, the present use of the land must be described briefly as a part of the complete soil description. The present use of the soil, the crops grown, and similar facts should be noted. *It is of utmost importance that essential differences between soil types as regards crop adaptations, yields, and appropriate practices be described.* Such information must be had by direct observation in the field, for the most part, with and without interviews. Only rarely do two soils have differentiating differences as soils without a corresponding difference in productivity for native or crop plants. This does not mean that the soil surveyor must "find" the difference in crop ecology in every instance, but it does mean that all observable relationships should be recorded.

The necessary observations regarding the use capabilities of soil types cannot be made in connection with profile examinations alone but must be continued throughout the area. These observations must be made carefully and in a way to obtain information and interpretations on the basis of the individual soil types. The soil type is the important physical basis for the classification and extension of data and experience regarding land use. At the same time, information regarding use capabilities must be so presented that the relationships between soil types are clearly brought out, even when several soil types may make up one farm or other operating unit.

In a great many instances, information is available on soil types from experiments conducted by other agricultural research agencies. All reliable data of such kind should be used in developing what might be called the "agronomic definitions" of the soil types. Frequently the results of experiments located in adjoining areas on soil types similar to those within the project are useful. Care must be taken that the data employed are reliable and obtained under conditions comparable to those which could be expected on a normal operating unit.

In describing the use capabilities of a soil type, attention cannot be directed simply to the capabilities of a soil under the simplest system of management; frequently the responsiveness of the soil to more intensive systems of management is equally or even more important. Certain soils, for example, may be naturally unproductive for general or special crops but responsive to particular types of management. This responsiveness is itself dependent on the character of the soil type and in many instances is very important in the agronomic definition of the soil type. Actual yields on such responsive soils may vary greatly according to management. Such variations are to be expected and, rather than indicating variations within the soil type, prove responsiveness to certain management as a type characteristic.

UNITS OF CLASSIFICATION AND MAPPING

On the basis of their differentiating characteristics soils are grouped into categories which can be defined with suitable precision. Three categories are commonly employed in the classification of soils in the field—(1) series, (2) type, and (3) phase. The

grouping of these units into categories higher than soil series and finally into great soil groups will not be discussed in this manual.

Not all land can be shown on the soil map by the use of these three classificational categories alone. Occasionally areas of two or more soils, each belonging to a distinct classificational category, may exist in such an intimate and complex pattern that they cannot be separated on the soil map. Thus all units of classification are not necessarily mapping units. Two or more soils may be separated by important differentiating characteristics as far as soil classification is concerned, but such units of classification *must also have mappable* differences if they are to be used as mapping units. In addition to the units already mentioned, a fourth, called the "complex" is necessary. Strictly speaking, the complex is not a fundamental category in soil classification but a mapping unit defined as a combination of two or more series, types, or phases.

Certain types of land exist, which possess little or no definite soil character, due to extreme stoniness, sandiness, hilliness, or some similar quality. Such conditions are recognized simply as "miscellaneous land types."

The soil surveyor must have clearly in mind the definition of these five classes of mapping units, the characteristics which are concerned with each, and their relationships to one another. Mappable differentiating soil characteristics should not be expressed as phases, nor should purely physiographic or other features outside the soil itself be expressed as series or types. In those instances where soils have differentiating characteristics which are not mappable, the complex must be used.

THE SOIL SERIES

A series is a group of soils having genetic horizons similar as to differentiating characteristics and arrangement in the soil profile, and developed from a particular type of parent material. Except for texture, especially of the A horizon, the morphological features of the soil profile, as exhibited in the physical characteristics and thicknesses of the soil horizons, are not allowed to vary significantly within a series. These characteristics include especially structure, color, and texture (except the texture of the A horizon) but not these alone. The content of carbonates and other salts, the reaction, and the content of humus are included with the characteristics which determine series.

Each soil in a series is developed from parent material of similar character. Parent material for soil is produced through the forces of weathering from rocks. Similar parent materials may be produced from different geological deposits and in different ways, and unlike parent materials may be produced from the same rocks because of differences in weathering. It is the character of the parent material itself which is important. It is not necessary that the original rocks or the manner of the accumulation of unconsolidated parent material be uniform throughout a series.

Variations in texture, especially of the A horizon, are found within a series. In the early days of soil surveying a considerable range in texture throughout the entire profile was sometimes included within

a series. Significant differences in texture of the parent material are not to be included within a series as now defined.

This does not mean that every single observable characteristic in two soil profiles must be identical if they are in the same soil series. If this were true each profile would be a separate series, as no two are identical any more than are any two black spruce trees, two horned toads, or even two soil surveyors. Slight variations in the thickness of the individual soil horizons must be expected. Where such variations have a practical, but not a genetic, significance, they may be indicated by phases. Variations in the soil profile, quantitatively or qualitatively significant in the characterization of the soil as a natural entity, are recognized as series differences, and only these.

It is not easy to make a hard and fast rule regarding the variations allowed within a soil series. Ideally, and especially from the point of view of applied soil science, it might be said that mappable differences of importance to the growth of native or crop plants should be recognized, and only these. The first part of this suggested guiding statement can be accepted. All mappable differences in the soil profile significant to the growth of plants should be recognized in the classification. Inasmuch as science does not have at its disposal complete knowledge in regard to the relationships between soils and plants, this principle cannot be fully accepted. As applied soil science has progressed, the enormous practical importance of soil differences, thought to be only of academic interest a few years previous, have been demonstrated again and again.

The guiding principle in separating soil series might then be revised to include all differences in the soil profile. This cannot be accepted entirely, as certain characteristics can be determined only with great effort and may not be worth the time and expense involved. To illustrate: Two soils may have profiles closely resembling that normal for the Gray-Brown Podzolic group except that the C horizon of one has a pH of 6.8 to 7.5, due to the presence of calcium carbonate in the parent material, whereas the C horizon of the other has a pH of about 5.5 to 6.0. These soils should be separated, even though some trouble is involved. Most likely this characteristic will be associated with other accessory characteristics. From a practical point of view such a separation is important to applied soil science and agronomy. On the other hand, suppose a similar difference existed between two soils associated with the normal Gray-Brown Podzolic soils but developed on flat upland relief and characterized essentially by impervious, cemented, or very compact B horizons. With these soils the agronomic importance of the difference would be materially less than with the first pair, and the difficulty of making the necessary examinations would be greatly increased. From a practical point of view the separation probably would not be justified if no consistent external feature were associated with this internal characteristic.

A further restriction on the observable differentiating soil characteristics is that such characteristics must be mappable. Like the second example just explained, certain characteristics may be so difficult to observe uniformly that the time and expense involved is

not justified. Again two soil series may be so intimately mixed in small areas that their distribution cannot be shown on the scale employed in mapping. The field scale ordinarily used in soil surveying has already been discussed. Although this scale is not definitely fixed and can be adjusted according to the soil conditions, situations will frequently arise where complex soil differences cannot be shown on any reasonable scale. In such instances the soils will need to be grouped and mapped as a complex.

From what has been said, it is clear that no precise rule explaining exactly which characteristics are considered differentiating between series can be laid down for all conditions. Generally, it may be said that those observable and mappable characteristics which are known to have, or are likely to have, significance in the growth of native or crop plants are concerned. Through experience in the field and a wide appreciation of the findings in plant physiology and agronomy, the judgment of the soil surveyor must become tempered.

The soil series names are place names taken from the area where the soil is first defined, such as Miami, Hagerstown, Mohave, and Houston. In the early days of soil surveying many soil series were given a very broad definition, in fact, so broad in some instances that it became necessary to split the series into two or even several series after the soils had been more thoroughly studied and understood. For example, several soil series are now recognized for soils included with the Miami and Carrington as first defined. Although Carrington is a place name from North Dakota and the series was first mapped there, subsequent investigations have shown the soils to be significantly different in many ways from those given the same name elsewhere. Since the name had been widely used in other sections it was retained for soils in Iowa, and those in North Dakota were renamed Barnes. This development has caused a certain amount of unavoidable confusion, as soils shown on the older maps do not conform to the later, more precise, definitions. Recently, however, as the classification has been more nearly perfected, this confusion has diminished, and if the descriptions in the report accompanying the particular map being used are followed, their identity offers no difficulty.

As the same place names frequently occur in several parts of the country, care must be taken in correlation to prevent the use of the same name for different soils. When the soil surveyor makes his field-mapping legend each series should be given a place name. As it is of the utmost importance that each soil be mapped in accordance with its definition for the particular area, if any doubt exists in the mind of the soil surveyor about the identity of any of the series previously defined, it is always best to use local names during the progress of the work. In the final correlation by the inspectors, like soils will be given their proper names.

THE SOIL TYPE

The soil type is the principal unit of mapping and because of its specific character is usually the soil unit to which agronomic data are definitely related. Each soil series is composed of one or more types, differentiated on the basis of texture. The soil type name thus consists of a series name plus the textural class name determined prin-

cipally by the texture of the upper part of the solum. In soils with well-developed profiles the texture of the A horizon determines the class name. Where the A horizon is thin or poorly developed, the average texture of the upper 6 inches (or approximately equivalent to the cultivated surface layer of arable soils) is used as a basis for determining the class name.

In a few instances, the texture of the material at greater depths was given major emphasis in determining the class name before the present concepts were so precisely defined. This practice was adopted in distinguishing between certain soils whose principal variation is in the texture of the B horizon. For example, two soils having sand or loamy sand A horizons to a depth of 20 inches, and B horizons, in one soil of loamy sand and in the other of sandy clay loam, were given class names of sand and sandy loam, respectively. According to present usage, such soils would be placed in separate series, but as certain soil types thus defined, such as Norfolk sand and Norfolk sandy loam, are so well established, the old nomenclature is retained. There are only a few soil types thus defined.

It is not to be presumed that there is no difference whatever between soil types within a series other than the texture of the upper part of the solum. If there is no important difference, except texture, the class name is determined (with the exception noted) from the upper part of the solum, but at the same time the texture may vary elsewhere in the soil. To illustrate: Miami silt loam and Miami loam have a silt loam and loam texture, respectively, in the upper part of the solum. The B and C horizons of Miami loam have, on the average, a slightly lower percentage of the finer separates than those of Miami silt loam, but the other characteristics of the soil are similar although allowed to vary qualitatively to the same extent that is expressed by the differences in the class name of the type.

In instances of soils developed from stratified parent material, the question frequently arises in regard to where differences should be expressed by type and where by series. For example, suppose a soil is developed from heavy lacustrine clay and in places overlain by varying thickness of sand. Such a soil developed on clay is illustrated by Ontonagon silty clay loam. As the sand layer on the top becomes thicker, silt loam, loam, and sandy loam types are produced. The question arises as to how much of the soil must be developed from the sand before the soil is placed in a different series. In such an instance, the outstanding characteristic of the series is the heavy clay and at least a part of the solum must be developed from the clay for the soil to be included as a type within the Ontonagon series.

With Bog soils, the textural class names used with other soils are not applicable, and there are no type designations in a strict sense. In Bog soils having well-decomposed surface soils, high in ash, the designation muck is used; and those which are not well decomposed and are low in ash are called peat. This mucklike surface soil may be developed by soil-building forces from peat or may be inherited from the parent material. Thus, the complete soil name of a Bog soil consists of the series name and the word peat or muck as the case may be, as Carlisle muck and Greenwood peat. Intermediate types are called peaty muck.

THE PHASE

A phase of the soil type is defined and shown on the soil map on the basis of characteristics of the soil, or of the landscape of which the soil is a part, that are of importance in land use but are not differentiating characteristics of the soil profile. Important variations in relief and stoniness are typical examples.

Differences in the texture of the upper part of the soil, of sufficient significance to be recognized in mapping, are indicated by type designations. Similarly, important differences in structure and other characteristics of the solum should be recognized by series definitions. The most common phase designations include variations within the soil type as to slope, erosion, stoniness, and drainage, that are important in land use but not expressed in mappable differentiating soil characteristics.

SLOPE

Each soil type has its characteristic range in relief, and any marked departures involve a change in those characteristics of the soil itself which determine series. With some soils this range is rather narrow, whereas with other soil types, within the range allowed, there are frequently differences in relief of great significance to land use, especially in respect to cropping, even though there is little difference in the character of the soil or its capabilities for native plants. It must be emphasized that these relief phases are primarily concerned with the relationships of the particular soil type to land use. The suitability of land for the use of agricultural machinery, and, in areas where soil erosion is a problem, the erodibility of the soil depends, in part, on the slope. From the point of view of land use, there are five principal classes of land defined according to relief as follows:

A. Nearly level to level land, on which external drainage is poor to slow. From the point of view of slope there is no difficulty in the use of agricultural machinery nor is there likelihood of erosion.

B. Gently undulating land, on which external drainage is good but not excessive. All types of ordinary agricultural machinery may be used with ease, and there is little likelihood of serious soil erosion.

C. Gently rolling lands, on which external drainage is good to free but not excessive. Ordinary agricultural machinery may be used, but the heavier types of equipment with difficulty. On soils subject to erosion there is likelihood of water erosion where intertilled crops are planted.

D. Strongly rolling land, on which agricultural machinery cannot be used. External drainage is free, but sufficient water is available for a good grass cover. Soil erosion is likely to be serious on land planted to cultivated crops.

E. Steeply sloping and hilly land, on which external drainage is so excessive that good pasture grasses cannot maintain themselves, although trees may be able to do so.

The important criterion of these classes is not the percentage of slope but their land-use definitions. In itself slope has a limited significance; *its importance can only be studied and evaluated in respect to a definite type of soil.* For example, some soils with a 5-percent slope erode easily when devoted to clean cultivation, whereas others erode very little under such treatment, even with slopes in excess of

50 percent. In many sections of the country the division lines will be about $2\frac{1}{2}$, $7\frac{1}{2}$, 15, and 25 percent of slope, respectively, but in some sections these figures, especially the last two, may be twice their suggested value, and in other sections they may be lower, especially the second one. The division lines, especially in regard to erodibility, may not have the same values in terms of percentage of slope on different soils in the same region. In many areas that are taken up for survey, there is no land of the E class or even of the D class.

The importance of differences in slope varies in different sections, but on the whole it is an important matter, and the final soil map must be so made that these relationships are clearly expressed by the definitions of the soil types and phases if the objective of the survey is to be reached. In a hill-valley section in the region of Pedalfers there are three principal use groups of rural land: Cropping, grazing, and forestry, in the approximate order of their intensity. The boundaries of land capable of these uses are of first importance, and in many instances they are determined by differences in slope. Where the soil type does have a range including one or more of these relief classes, one class is selected as typical for the soil. and the others are shown as phases in detailed soil mapping.

Considerable study is required before the definitions of the relief of the soil types and phases can be made accurately. Differences in erosion due to differences in land use should not be interpreted as indicating relief conditions. The classes must be so defined that the boundary lines between them are readily recognizable. This requires considerable judgment. Having established suitable mapping units, the slope in percentage should be determined. In figure 14 is shown a suitable instrument for this purpose. Unless care is taken and the types and phases clearly defined as to relief, the tendency will be for numerous subphases or subclasses to be established and the mapping become hopelessly involved. In the survey of areas where special techniques or conditions are involved, as with land proposed for irrigation, special slope differences may be required, even though these are not intended for publication on the final lithographed map.

In the final correlation, the relief phases will be named by the use of terms representing the departure from the relief defined for the typical soil, as sloping phase, rolling phase, steep phase, and flat phase. In many instances where the soil survey is used as a basis for detailed land classification, at least a part of the data may not need to be shown on the published soil map.

EROSION

As with slope phases, erosion phases cannot be defined in precise physical terms applicable to all the various sections of the country where there are soils subject to erosion. The soil surveyor must distinguish between two general types of erosion: (1) Natural erosion, or that normal for the soil type under the native vegetation; and (2) accelerated erosion, or that brought about locally as the result of incorrect land use. Phases established to show the former are designations of natural land types, as are relief phases; whereas the latter conditions are transitory. For example, a land type only

recently placed under cultivation may show little erosion under a method of management which can be expected to lead to erosion as shown by other areas of the same kind of land under the same management for a longer period. In the final published soil map only the relatively permanent conditions are shown. In areas where soil erosion is a problem, however, in order to reach such an objective as a basis for detailed land-use planning it may be necessary that the existing erosion conditions be shown in greater detail on the master soil map made in the field than is required for the published soil map.

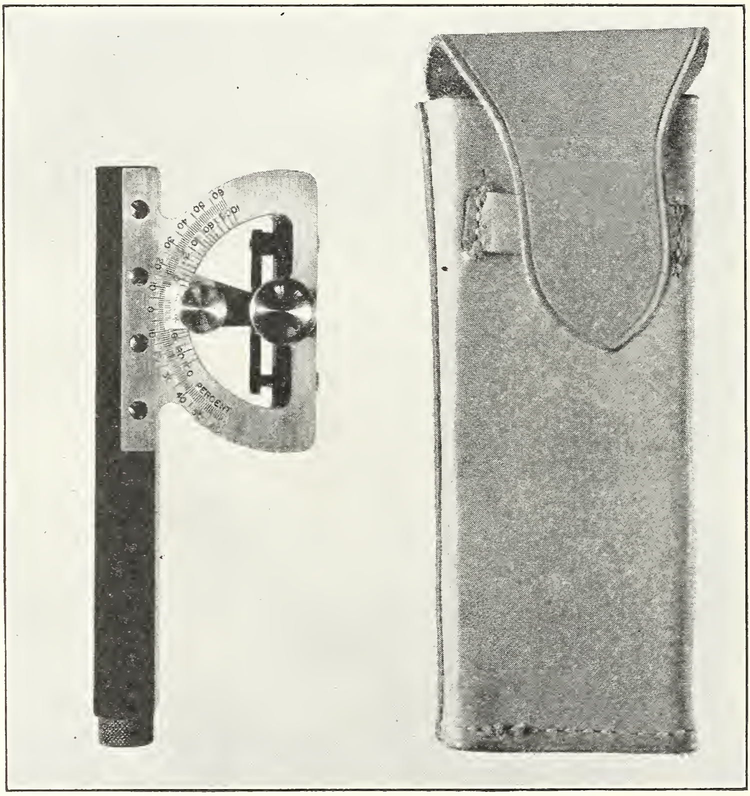

FIGURE 14.—Abney hand level, with case.

The number of categories to be recognized and their definitions will depend on the scale employed in mapping and the requirements of the particular objective. The problem of erosion mapping as such, for special studies, cannot be discussed in detail here. The general principles involved in the mapping of erosion in connection with the usual detailed soil survey can only be generally stated, as each area has its own peculiar problems. As with all other parts of the mapping legend the test of the categories for any particular feature is: Can the land be placed in the categories and does the map show those differences of importance in the operation of individual farm units?

The erodibility of the soil is a characteristic of the soil type and should not be shown by phases. For each soil type of a particular slope class there is a normal degree of erosion, or that which maintains the soil profile at its normal depth for the type under the native vegetation.

To determine the degree of erosion when the soil is under cultivation, the depth of the solum must be compared to that of the virgin soil. This depth should not include horizon A_0 or A_{00}. Frequently there is a marked difference in volume weight as the result of cultivation, and the thickness of the A horizon is reduced without any loss of soil. Since most soils have some range in depth of the A horizon under natural conditions, the average depth, *and its range*, of the solum of the normal soil type must be compared to the average depth, *and its range*, of the eroded phase of the type. This can be done accurately for important differences significant in land use, but if too much detail is attempted the mapping may become hopelessly confused. The thickness of the solum will, of course, vary with different soil types and to some extent with relief phases within a soil type. From both the practical and scientific standpoints, it is highly important that erosion phases be defined in relation to each particular soil type concerned. Having established the standards, the mapping must be done on the basis of the soil as found, not on the basis of soil gone.

This accelerated erosion due to incorrect land use may have reduced the depth of soil more or less uniformly by sheet erosion, irregularly by gullying, or by both. All the various degrees may be found, but ordinarily two or three phases differing in degree, will be adequate, as slightly eroded, moderately eroded, and strongly eroded phases. These may need to be recognized for sheet erosion, gully erosion, and for a complex of the two. The separation between the second and third classes should represent the boundary line between land generally suitable for the most intensive use group of which the natural land type is capable and that suitable only for a less intensive use. In most instances, the use groups concerned will be cropping on the one hand and grazing and forestry on the other, but the division may represent the difference between land suitable for grazing and waste land. On the final soil map this distinction is the one which should be shown; but finer distinctions may be made in the field, where required to reach the objective of the survey.

Occasionally, "silted" or "overwash" phases are necessary to indicate conditions produced by the fresh deposition of alluvium over a soil type.

STONINESS

Stony, cherty, cobbly, or gravelly phases are used to indicate soils which vary significantly from the soil type only in these features. If a soil type is characterized by a consistently high content of such fragments, their presence is indicated in the textural class name, such as stony loam, gravelly sandy loam, or cobbly loam. Of these conditions, stoniness is the most important, and in large sections of the country, especially in mountainous areas, and in glaciated areas, it may be a determining factor in land classification. With those soils naturally productive for crop plants and having a favorable relief for crop production, the degree of stoniness is especially

important. Of first importance is the boundary line between degrees of stoniness that determine capabilities for land use. Thus, if a soil type is suitable for crop production, but in general the stony phase is not, it is of the utmost importance that the definitions of the type and phase be made so that the boundary line accurately separates the potential cropping land from that not suitable for crops.

For the usual detailed soil map published in color on a scale of 1 inch to the mile, subphases of stoniness ordinarily are not shown. Where the field maps are to be used as a basis for detailed land classification, however, greater detail than that indicated on the lithographed maps is sometimes required. If this mapping of subphases showing degrees of stoniness requires considerable detail, a secondary field sheet should be employed. Usually three classes of stoniness in addition to the stone-free land will be sufficient to indicate the necessary detail as follows:

0. Land essentially free of stones.

1. Land having enough stones to interfere with cultivation unless removed but not so numerous as to preclude the practicability of their removal.

2. Land having sufficient stones to preclude the practicability of their removal, in order that the land may be cultivated, but not enough to reduce its capabilities significantly for permanent pasture if other factors are favorable.

3. Land so stony as to be unfit for cultivation and of no use, or of only limited use, for pasture. Land of this character is commonly included with the miscellaneous land types which will be described subsequently.

The most important distinction lies between class 1 and class 2. For the published soil map classes 2 and 3 are grouped together as the stony phase or, commonly, class 2 is shown as the stony phase and class 3 as one of the miscellaneous land types if the stoniness is of such a nature as to render the land essentially useless for either cropping or grazing. These definitions are, like those of the relief classes, in terms of land-use capabilities and are more or less arbitrary from a strictly scientific point of view. The quantitative definition of the classes in cubic yards per acre will vary somewhat in different sections of the country depending on the other factors influencing the intensity of land use. A set of figures found useful in several places are, 2 to 20, 20 to 50, and over 50 loads (equivalent to cubic yards) per acre for the three classes of stoniness. Like the definitions of relief phases in terms of percentages the figures must be subject to revision in different sections, in order to maintain the definitions according to land-use capabilities.

Small spots of the stony phase may be indicated by symbols, and where this is done the symbols employed must be carefully defined as to the degree of stoniness and the size of the area indicated. For the published soil map classes 2 and 3 defined above are grouped together for the stony phase when shown by symbols. Thus each stone symbol may be used conveniently to indicate 1¼ (½–1¾) acres or 2½ (1–3½) acres of the stony phase according to the detail necessary. Thus ½ , 2, 5, 10, and 15 acres of the stony phase will be indicated by 1, 2, 4, 8, and 12 symbols, respectively, or by 0, 1, 2,

4, and 6 symbols, according to the second suggestion. The same definitions may be given to the symbols showing small areas of the cherty, cobbly, or gravelly phase.

DRAINAGE

In most soils significant differences in drainage are reflected in differentiating characteristics that determine soil series. Occasionally, however, small differences, highly significant in land use, are not accompanied by significant differences in the soil profile. This is especially true of soils developed from alluvium which have developed little or no profile characteristics. With such soils, important differences in drainage can be indicated by phases. Again soils developed in benchlike positions, such as stream terraces, may have small differences in the drainage beneath the solum, which are important to land use but are not reflected in the soil. Indirectly related to drainage is the likelihood of overflow. Here again young soils may vary significantly in this respect without corresponding differences in soil characteristics, and high-bottom phases may be defined for the separation of part of a soil type distinctly superior from the point of view of capabilities for crops.

The soil surveyor should never represent the fundamental differences in soil brought about by differences in drainage, as phases. This legitimate use of drainage as a criterion for phases is very closely limited but nevertheless important with some soils.

OTHER PHASES

Many designations previously used as mixed phase or alkali phase, are essentially complexes and will be described under that heading. The mapping of differences in salt content is discussed in a special section. Phases have been used incorrectly in some instances to indicate differences of the order of series or type.

Physiographic phases, in addition to those necessary for indicating relief, drainage, or overflow, should be avoided. Many of those suggested from time to time have no definite significance, either scientifically or practically, partly because of the difficulty of precise definition. There are a few legitimate uses of such phases, however, where they can be defined accurately and where relief phases do not give a satisfactory representation of actual conditions. For example, a sandy soil type derived from stratified materials may have an essential counterpart where the sandy material had been moved about by the wind and the surface left hummocky. In a strict sense such a condition is a relief phase complex and may be best mapped and defined as a hummocky phase or as a dune phase, depending on the nature of the mounds. A few other examples may be met but, for the most part, there is little need for additional physiographic phases. In soil mapping no attempt should be made to show geology or physiography as such. The soil and other physical features of importance in land use are to be shown in categories defined in such a way that the capabilities of land for use may be seen from the map.

Phases based on slight changes in color are rarely justified. If the color of the soil varies significantly it should be recognized as

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a different series. If the color difference is not significant it should not be recognized at all in the mapping but should be clearly defined in the soil-survey report. An exception may be made in a few instances where the color is inherited from the parent material and has little significance to the soil itself. Differences in parent material which are accompanied by little or no difference in the soil itself are rarely of sufficient importance to separate, but occasionally, especially where the solum is thin, it may be necessary. Usually such separations can be sufficiently described, both as to character and location, in the report.

Where phases according to depth are used, especial care must be taken to define them. The terms "deep phase" and "shallow phase" have been used to indicate (1) the thickness of the A_1 horizon, (2) of the A horizon, (3) of the solum, and (4) of the solum plus parent material over some lower strata, especially of hard rock. Instances will arise where differences in depth, especially to hard rock (4), are legitimately shown as such by phase designation. Less commonly, differences in the depth of the A horizon (2) may be shown adequately by phase distinctions. Aside from these conditions, however, phases can rarely be used with correctness. Differences in depth due to accelerated erosion should be shown as erosion phases, but most of the significant variations in depth are series differences and not phase differences.

THE COMPLEX

The mapping unit known as the complex has not been conceived clearly by many soil surveyors. These complexes are not categories of classification but are cartographic units composed of such intimate mixtures of series, types, or phases that they cannot be indicated separately. Complexes are frequently called phases on the published soil map and described in the soil-survey report. This is satisfactory from the point of view of those using the maps, but from the point of view of soil classification there is an important difference which must be conceived clearly for logical results.

A phase represents a uniform change in some character other than a differentiating soil character, but a complex represents a mixture of two or more series, types, or phases, that cannot be separated because there are no mappable differentiating characteristics. A few complexes, unfortunately, have been given separate series names in the past, whereas they were in reality mixtures of two series. Many of the Solonetz and Solonchak soils occur as spots within other soils and the two so intimately mixed that the areas can be shown only as complexes. Intimate patterns of Bog or Half-Bog soils with upland soils must be mapped as complexes, sometimes called in the past mixed phases. It is better, however, to use the series names of the two dominant constituents of the complex as Rubicon-Rifle complex or Saugatuck-Newton complex. The description of the complex should include a description of each soil and of the pattern which they make. A more useful map will be made in this way than by trying to draw boundaries according to the relative predominance of each type where the intimate detail cannot be mapped.

Frequently textural differences within the series cannot be separated on the map, although the series can be shown. This is espe-

cially true of alluvial soils, but the condition is by no means confined to them. Such a complex can be given the series name only, as Griffin soils, undifferentiated, or Guin soils, undifferentiated. Again the soil type may be mapped out, but relief phases of great importance within the type may be mingled in such an intricate pattern that they cannot be separated. This matter was touched on in discussing physiographic phases. Although such conditions may be physiographic, they are more logically conceived as phase complexes. A landscape may consist of nearly level land with steep mounds, too small to indicate individually, scattered through the area. Such a mixture of phases may be indicated as Mancelona cobbly loam, mound phase, more strictly a complex than a phase. Similarly, a sheet-eroded phase of a soil type and the normal soil for the type may be so confused that a complex of the two must be recognized.

MISCELLANEOUS LAND TYPES

Although the soil map is primarily concerned only with soil, other areas of land that are without a definite soil must be indicated on the map. Many terms are in current use for such land, and the principal ones of these are defined as follows. It will be noted that some of them may also be complexes or parts of complexes.

Alluvial soils, undifferentiated.—Alluvial soils, undifferentiated, is a complex of various alluvial and young soils. This term is to be preferred to "meadow." Where the mixture consists of established soil types, the area should be mapped as a complex, using the series name, as Congaree soils, undifferentiated.

Coastal beach.—Coastal beach designates lands which are recently uncovered lake or ocean beds with the strand or wave-worked beach, along large lakes or oceans. The land may be covered with water during high tide or stormy periods. If the material is predominantly sandy the term "beach sand" is used.

Dune sand.—Dune sand designates shifting dunes or those only partly fixed or so recently fixed that no soil has developed.

Made land.—Made land includes filled-in areas, such as those in cities and near industrial plants. The material may be a mixture of earth and trash.

Mines, pits, and dumps.—Mines, pits, and dumps include areas of land mutilated by mine operations.

Peat.—Peat is applied to a complex of unclassified peat. If the surface of the peat is fairly well decomposed and has a high content of ash the term "muck" is used.

Riverwash.—Riverwash includes those parts of the present stream bottoms that are frequently covered with water and subject to movement. The land consists of stony, gravelly, and sandy material that is generally bare and essentially useless for plants.

Rock outcrop.—Rock outcrop includes exposures of bare rock occurring in areas sufficiently large to delineate on the soil map.

Rough broken land.—Rough broken land includes areas having steep or very steep relief, which in many places may be badly gullied or broken by intermittent drainageways and may include narrow winding ridges and steep knobs. Where the landscape is almost entirely a result of rather recent erosion the term "rough gullied land" is used.

Rough mountainous land.—Rough mountainous land refers to very rough land, dominantly stony in character but including small areas of land suitable for cropping and, in places, considerable land suitable for grazing. This mapping unit is essentially a complex of rough stony land with small areas of soils. It is not recognized in detailed soil mapping, only in reconnaissance soil surveying.

Rough stony land.—Rough stony land includes land having steep relief accompanied by many outcrops of solid rock and large boulders. The land is too steep and otherwise unsuitable for either cropping or grazing of any consequence.

Scabland.—Scabland includes areas of nearly level or sloping land having a thin layer of soil intermingled with rock outcrops, generally volcanic rocks, as basalt. The land may support a scant vegetation.

Smooth stony land.—Smooth stony land includes land similar to rough stony land but having less pronounced relief. It consists largely of ledges or outcrops of solid rock and boulders, with a small amount of soil material.

Steep hilly land.—Steep hilly land includes land with steep slopes which are not stony and not recently eroded. In most instances such land will be shown as a complex, such as steep hilly land, Madison-Louisa complex.

Swamp.—Swamp is used for a complex of poorly drained immature soils, mainly inorganic and usually forested. Where the grass vegetation predominates the term "marsh" is used.

Tidal marsh.—Tidal marsh includes wet land bordering bodies of salty or brackish water and periodically covered by the tide.

MAPPING SYMBOLS IN LEGEND

After the descriptive legend has been prepared, each soil type, phase, complex, and land type must be given a particular symbol. It is usually most convenient to assign numerals to the soil types, complexes, and land types, and letters or numerals to the phases. Where the mapping is done in considerable detail it may be convenient to employ fractions such that certain numbers and letters are employed in the numerator and certain others in the denominator. It is neither necessary nor desirable to suggest a uniform system for all areas. The symbols should be as short and as clear as possible and so arranged as to be easy to remember. Since the problems in any two areas are rarely identical, the system of symbols used must vary from place to place, in order to reach these objectives.

Some examples of symbols will suffice to illustrate some of the possible devices. A soil type may be shown as a simple number, say 14. Relief phases might be shown as 14C and 14D. Further phases for stoniness might be shown as $14S_1$, $14CS_1$, $14CS_2$, and so on. If, instead of phases for stoniness, there are phases for erosion, they could be shown in the same way. If several phases and present land use are to be shown on an unusually detailed map, a fraction may be employed for convenience as:

$$\frac{\text{Soil type—relief—stoniness}}{\text{erosion —land use}} \quad \left(\frac{14CS_1}{S2\ C}\right)$$

If one of these factors, such as stoniness or erosion, is not important in the area, it would be eliminated from the fraction and other factors, such as drainage or saltiness, added if necessary. The particular form of symbols will thus depend on the objective of the mapping, the detail shown, and the nature of the landscape. Long and complicated symbols, such as the one illustrated in the last example, should be avoided wherever possible.

In addition to the symbols used within areas enclosed by boundaries, others must be used for small spots of a stony phase, a wet phase, a rock outcrop, and similar features not enclosed by boundaries. Wherever possible the standard symbols should be employed, but occasionally it may be necessary to use special symbols for some special feature or condition. Above all, the mapping legend must define every such symbol, quantitatively and qualitatively. If stone symbols are used, for example, the legend must define precisely the area and degree of stoniness each symbol represents. The same is true for symbols showing rock outcrop, gravel, wet spots, depressions, sinks, salty spots, and similar features.

The symbols for drainage and cultural features have been discussed. These are well standardized, but special deviations are sometimes necessary, especially when the scale of the map is very small. These symbols, including those which are standard, together with their definitions, should be included in the field legend, in order that no possibility for confusion may exist.

It is the responsibility of the chief of party to be certain that *all symbols, of whatever kind, appearing on the soil map are fully defined and included in the mapping legend*, and that there is no confusion or duplication of symbols. No mapping should be done by any member of the party until such a legend has been furnished him. Even if the use of certain symbols appearing in a few places has been discontinued, they should be included in the legend and a notation made of their restricted use.

PREPARATION OF THE SOIL MAP

After the base map is available and the soil-mapping legend prepared, the work of constructing the soil map can begin. Where the soil surveyor must construct the base map it is most convenient to lay out the primary traverse before any soil mapping is attempted. After the primary traverse is made, the remainder of the base map can be constructed as the soil map is made. Where beginners are in the party it will usually save time and trouble if the primary traverse is made by experienced men and these sheets (without removing them from the traverse boards) given to the less experienced men for completion.

LOCATION OF SOIL BOUNDARIES

Soil boundaries must be located on the line of traverse and their course sketched accurately on the base map. Although the soil boundaries are not actually traversed *they must be observed throughout their course* in detailed soil mapping. A study of the soil types and phases to be shown will commonly show external features which assist in the sketching of the boundaries after they have been located

on the line of traverse. That is, a great many of the soil boundaries are coincident with such easily observable features of the landscape as the foot of a slope, the crest of a ridge, the margin of an escarpment, or changes in vegetation.

But not all soil boundaries are so easly discernible. For example, several soil types, varying significantly in their capabilities for agricultural use, may be developed from lacustrine deposits and exist in an intricate pattern without any marked external evidences in the terrain. Under such conditions additional time and care are required for accurate mapping. Although external features are useful in locating boundaries, the identity of the soil must be established by internal examination and not from the external evidence alone. In all instances, frequent internal examinations of the soil must be made, and in the absence of external evidences, the boundaries must be located entirely by examinations with a spade or auger.

Sometimes soil boundaries are sharply defined and clearly evident; again they represent the midway line within a transitional zone as one soil type gradually merges into another. For example, the boundary line between a well-drained upland soil and a Bog soil may be very abrupt at the foot of an escarpment. Again there may be a very gentle slope from the upland soil to the Bog soil with a broad transitional belt, occupied by Half-Bog soils, and transitional belts between the three types of soil. Care must be taken to place the soil boundaries in the middle of the transitional belt.

The boundaries are located precisely at the points of traverse and sketched accurately in relation to features shown on the base map, as dotted pencil lines, from observations between these points. It is highly important that the boundaries be accurate in reference to roads, land lines, houses, streams, and other local points of reference. It has been mentioned that in the average detailed soil survey no feature should be in error more than 125 feet. Even within this limit, prominent features must be shown in proper relation to one another. For example, even though a house might be shown within 50 feet of its true position, if it were placed on the wrong side of a road, a section line, a stream, or a soil boundary, the error would be serious and the map not acceptable. The beginner will find it necessary to make frequent shots with the alidade and measurements to the side before angles and distances can be estimated with sufficient accuracy for sketching. Especially in reconnaissance mapping, side points through which boundaries pass, can be located conveniently by graphic triangulation.

Only the skilled and experienced soil surveyor can estimate distances greater than 40 rods under the best conditions, and a beginner should have a definite check on all estimations over a few rods. Variations in the formation of the landscape introduce many well-known illusions in respect to distance, which mislead the beginner. For example, equal distances when viewed over water, cleared land, brush land, and through trees, do not appear equal to a beginner. The distance across a smooth valley appears very different than a similar distance across a valley with low hills within it. Soil boundaries drawn in reconnaissance mapping may not be observed throughout their course but between points of observation are sketched on the basis of the general appearance of the landscape. More skill and

experience in the interpretation of external features are required here than in the detailed soil survey.

In the practical job of soil mapping it must be recognized that all soil boundaries are not of equal importance. The boundaries that separate soil types or phases with capabilities in different use groups are of first importance. For example, the boundary line between well-drained land and poorly drained land is of first importance. The boundary lines between land suited to cropping and that not suited to cropping are more important than those separating various types within either group. Such primary boundary lines must be drawn with especial care and accuracy.

SIZE OF AREAS SHOWN

It is sometimes difficult for the chief of party to instruct his assistants as to the minimum size of areas of distinct soil types or phases that are to be separated from other types and to achieve uniformity of mapping in this respect. Despite the difficulty, uniformity of mapping is essential, and much attention needs to be devoted to this problem, in order to meet the objectives of the work effectively and economically.

No categorical definition, applying to all conditions, can be laid down covering this point in terms of area. In the detailed soil survey, areas which influence significantly a unit of operation should be indicated. If, for example, a small spot of excessively stony land, wet land, or steep land, occurs within an area otherwise suitable for crop production it should be shown even if only one-half or 1 acre in size. Such small areas of distinctive land types must be shown ordinarily by special symbols rather than as areas enclosed by boundaries. On the other hand, if two soil types are similar and, although varying somewhat in their crop ecology, small areas of one within the other do not significantly influence the use of the land, areas less than 5 acres should not be separated. With soil types suited only to some extensive use, such as grazing or forestry, the minimum will be considerably higher, depending on the objective of the soil survey.

Thus, the more important the soil boundary, the smaller will be the minimum size of the areas to be enclosed by it. In instances of small areas of distinctive importance, care must be taken not to exaggerate their size on the map. By the judicious choice of definitions and symbols, small areas can be indicated with sufficient accuracy without drawing actual boundaries. In intimate, intricate mixtures of two or more types in areas so small that the land must be used all together without differences in treatment, the soils should be mapped as a complex rather than attempting to separate them, where this cannot be done accurately. *No boundaries should be placed on the detailed soil map unless they can be sketched accurately.* If difficulty is experienced in mapping observed features by trained surveyors, it generally will be found that some part of the mapping legend is not logically developed or arranged.

SECONDARY SHEETS

Secondary sheets may be used for secondary traverses where, for some reason, it is impractical to carry the master map, as in heavily

wooded areas. In extreme instances, the plane table is scarcely usable at all except on the roads, and the chief part of the mapping must be done on sheets carried in the notebook. In unusual instances, these sheets may be copied in ink and considered the final field copy of the map, but ordinarily this is not done, and it should be done only under special instructions. The data from the secondary sheets are transferred carefully to the master map as soon as convenient after completion but are filed for possible future reference.

Again secondary sheets may be used for the entire area to show data in addition to those included on the master map. Their use for this purpose should be limited. The data not intended for the final published soil map, such as subphases of stoniness or erosion and land cover, may be mapped in order to reach some special objective. Oil-treated paper is preferable for such uses.

Field notes to accompany the map should be made for any special conditions not adequately expressed by the map itself. These will be especially helpful in the early part of the work, before the legend has been whipped into final form. Any departures from the legend should be noted on the spot and brought to the attention of the leader of the party as soon as possible. The chief of party must insist that beginners keep such notes of their mapping, in order to assist him in checking their work, both in the office and in the field. It must be remembered that a much greater degree of accuracy and uniformity can be realized by the use of standard mapping symbols than by written notes. As a matter of fact, when copious field notes become necessary to any great extent, that in itself is sufficient evidence that the legend is not logically arranged or is improperly understood by the surveyors.

CHECKING FIELD SHEETS

Each field sheet must be carefully checked with all adjoining sheets, in order that there may be no discrepancies as to the base map or soil map. This should be done both before and after the sheets are copied in ink. The separate sheets should also be carefully examined for any open boundaries, unlettered or unnumbered areas, or other omissions. Each surveyor should check his own sheets and where possible, they should be rechecked by some other worker, in order to be certain that every part of the map is complete and entirely legible. The chief of party should check each sheet in several places in the field. With beginners the sheets will need especial care in field checking which should be done before they are copied in ink.

The field maps must be given a careful final checking by the chief of party before being sent to the office for preparation for publication. If there are any omissions on the map or in the legend, the costs for drafting are greatly increased and the publication delayed. It is, therefore, one of the principal responsibilities of the chief of party to see that all maps and legends are complete in every detail.

INKING FIELD SHEETS

Field work is done with pencil in areas where the soil-survey party makes its own base map. After the primary traverse is completed

and closed it is best to trace at least the roads in ink. As the final map is completed it should be copied with ink, although the margin of the field sheets should not be traced with ink until they have been carefully checked to the adjoining sheets. As has already been pointed out, the work of beginners must not be inked until it has been checked in the field and approved by the chief of party.

Only waterproof inks are to be used on soil maps. Streams, drainageways, and bodies of water are to be shown in blue. A small quantity of yellow or black must be mixed with the blue, in order that these features will be clearly reproduced when the maps are photographed. Only a small quantity of the yellow or black ink is required, and if black ink is used alone, care must be taken not to reduce materially the contrast between the blue and black lines. Section lines or other land lines where there is no road are shown with red ink; other cultural and physical features are shown with black ink. A ruling pen can be used very conveniently for roads and land lines, but most of the map must be made freehand with a crow quill or a fine lettering pen. Since the maps are made on a comparatively small scale, lines and symbols must be fine and distinct, in order that the photographs may be clear and legible. Neatness, but not artistry, is of the utmost importance for the work to be interpreted and published accurately. The lettering of towns, streams, and other features should be done last. Plain legible lettering is all that is required. Each sheet must carry the name of the area as well as definite reference as to its position within the area. Erasures of ink can be made with a knife only to the extent of removing the ink from the paper. They may be completed with a fine sand eraser and finally with a plain rubber eraser. If the surface becomes soft and cannot be restored by burnishing, a thin coat of collodion usually will restore an inking surface.

It has been the practice to color the field sheets after inking, using a different shade for each soil separation. This has a distinct advantage of making obvious any omissions on the map. The coloring of the sheets aids in making them complete and assists in correlation and the preparation of the report. Since practically all of the field sheets must be photographed, coloring either should be postponed until after the sheets have been photographed or the pencils used lightly and the color scheme arranged in such a way that the coloring will not interfere with photographing.

PREPARATION OF THE SOIL-SURVEY REPORT

The soil-survey report is a vital adjunct to the soil map. In it the soils are described as observed in the field and indicated on the map and their capabilities for various uses explained. The present uses and management of the soils are described, together with recommendations for the future. In giving meaning to the mapping units shown on the soil map, the report serves as an expanded descriptive legend. Without an adequate report describing the soils and explaining their important characteristics in relationship to their capabilities for use, the soil map is of little use to the layman.

The report and map are largely concerned with specific information gained by observation in the field, supplemented with data obtained from the laboratory, greenhouse, and experimental field.

Of particular importance to the soil surveyor are the results of practical operators using the soil for various crops under various types of management. Certain generalizations regarding the physical, social, and economic conditions of the county or area as a whole are important and necessary as a general frame of reference within which the more specific information finds its usefulness. Nevertheless, the principal function of the soil-survey report is to give the available specific information regarding each of the individual mapping units, their relationships to each other, and especially their relationship to an operating farm.

OUTLINE OF REPORT

In order to achieve some uniformity in the treatment and arrangement of subject matter in the report, especially for the convenience of those using large numbers of these reports, the outline which follows has been prepared. This outline cannot be followed blindly, as each area has its own particular features and problems requiring emphasis, and certain sections, given only broad headings, must be carefully organized in subdivisions.

GENERAL ARRANGEMENT OF MATERIAL IN THE SOIL-SURVEY REPORT

1. Description of the area surveyed.
    - (A) Location and extent of the area.
        - (1) General location within the State or Territory.
        - (2) Distance of county seat or principal town from one or more important places.
        - (3) Size of area in square miles.
    - (B) Physiography.
        - (1) Mention of the physiographic division of the United States in which the area is located.
        - (2) General description of the physiography and geology of the area.
    - (C) Relief.
        - (1) Discussion of any modification of the physiographic surface by natural dissection.
        - (2) Sketch map of relief areas if such a sketch is of material assistance to the discussion.
    - (D) Elevation.
        - (1) General elevation of the area and ranges in elevation.
        - (2) Altitude of some of the main topographic features.
        - (3) Altitude of towns or other known points. (Cite authority for data.)
    - (E) Vegetation.
        - (1) General but brief discussion of the vegetation, including especially the original and present forests, grasses, or shrubs. (Ordinarily there should be no detailed description of species unless this is important where many comparatively uncommon plants are mentioned. The

common names should be used, but a glossary of botanical names should be given, especially where noncrop plants need to be discussed at length.)

(F) Organization and population of the county.
 (1) Date of settlement.
 (2) Important historical data.
 (3) Source and distribution of the population.
 (4) Nationality of the settlers. (To be supported by census data.)

(G) County seat and principal towns.
 (1) Name of county seat.
 (2) Principal towns and their relation to the agriculture of the area.

(H) Transportation, markets, and other cultural features.
 (1) Railroads and highways and the service rendered by them.
 (2) Any service rendered by steamship lines.
 (3) The disposition and marketing of farm products.
 (4) Condition of public roads.
 (5) Schools, churches, telephones, and other features relating to rural culture and social life.

(I) Industries.
 (1) Important nonagricultural manufacturing industries, mining, and other industries affecting the area should be mentioned and any relationship these have to the agriculture of the area noted. (The plants engaged in processing agricultural products, such as flour mills and cheese factories, are discussed under H (3).)

2. Climate.
 (1) General type, that is, oceanic, continental, etc.
 (2) Variations among seasons.
 (3) Distribution of rainfall during the growing season.
 (4) Influence of physiography and bodies of water on climate in different parts of the area.
 (5) Climate as a factor in the production of special crops.
 (6) Discussion on value of the data on average dates of frost and average frost-free periods.
 (7) Discussion on value of data on average annual means for precipitation.
 (8) Conditions, favorable or unfavorable, for farm work.
 (9) Tables from Weather Bureau of temperature, precipitation, and frosts.
 (10) Discussion of unusual weather conditions, such as winds, storms, and hail.

3. Agricultural history and statistics.
 (A) Early agricultural development of the area.
 (B) Important changes that have taken place in the use of the land since settlement.
 (C) Census data on the agriculture of the area as far back as available and up to and including latest census reports.

(D) Present condition of agriculture.
- (1) Use of fertilizers, lime, and other amendments.
  - (*a*) Amount and cost.
  - (*b*) Kind of fertilizers used.
- (2) Labor.
  - (*a*) Kind and availability of labor. (Do not discuss the specific wages paid in different farm operations as conditions change from year to year.)
- (3) Size of farms.
  - (*a*) General range in the size of farms and the size of the average farm. (To be checked by census data.)
  - (*b*) Any trends toward change in size of farms and the reasons for such change.
- (4) Tenure of farms.
  - (*a*) Percentage of farms operated by the owners and by tenants.
  - (*b*) Systems of rental, such as cash rent, share of crop, or other.

4. Soil-survey methods and definitions.
   - (1) Description of methods used in mapping soils.
   - (2) Definition of terms used in the description and classification of soils.
5. Soils and crops.
   - (1) General characteristics of the soils of the area.
   - (2) Systems of agriculture practiced.
   - (3) Relationship between soils and agriculture.
   - (4) Grouping of soils on the basis of capability for use.
   - (5) Brief description of each group.
     - (*a*) Agronomic relationships.
     - (*b*) Characteristics common to soils in the group that determine use.
     - (*c*) The names of series in the group and the characteristics of the types of the series brought into this group.
     - (*d*) Description of each type and phase of the group, including all the following features, if applicable.
       1. Describe each horizon as to—
          - *a*. Color.
          - *b*. Texture.
          - *c*. Structure.
          - *d*. Consistence.
          - *e*. Thickness.
          - *f*. Reaction.
          - *g*. Content of organic matter.
          - *h*. Stoniness.
          - *i*. Root penetration.
          - *j*. Salt or alkali.
       2. Important variations within the type.

3. Location and extent of soil.
    a. General location of the larger areas and definite location of areas of minor types.
    b. Estimate in square miles of areas of each type.
4. Relief.
5. Geologic origin of parent material.
6. Drainage (external and internal).
7. Native vegetation, if important.
8. Uses to which soil is put and crop yields woven in with capabilities of soil. Approximate acreage in different crops.
9. Management of the soil. Systems of management compared with those of area as a whole. Susceptibility to erosion or deterioration from other causes under wrong management.
10. Methods of drainage or irrigation.
11. Water supply if related to soil type.

6. Land uses and agricultural methods.
    (A) Capabilities of soils for use.
        (1) Crops, (2) native pasture, (3) forests.
        (2) Successful and improved methods of management as demonstrated within the area.
        (3) Results obtained by experiment on soil types or closely related types, including—
            (*a*) Use of various fertilizers, lime, or other chemical treatments.
            (*b*) Rotations.
            (*c*) Farm implements.
            (*d*) Prevention of erosion.
            (*e*) Tillage.
            (*f*) Drainage.
            (*g*) Varieties of plants.
            (*h*) Plant diseases, insect pests, and noxious weeds.

        (This discussion should be specific in respect to the separate soils.)

7. Drainage, irrigation, or alkali amelioration (not always necessary).
    (Indicate exact meaning of the term "alkali" in each particular report.)

8. Productivity ratings.
    (Instructions on this chapter will be supplied in each instance.)

9. Morphology and genesis of soils.
    (A) Location of the area with reference to the great soil groups.
    (B) Parent materials.
    (C) Factors of environment influencing soil development.
    (D) Description of normal regional profile and a few of the more important variations.
    (E) Character of intrazonal and azonal soils.

10. Summary.
    (A) Brief discussion of area and its agriculture.
    (B) Uses made of soils and reason for such use.
    (C) General statement of the character of the soils.
    (D) Brief description of the soil groups and their relation to agriculture.
    (E) Names of the principal soils, their characteristics, and their influence on the agriculture.

This outline should be followed in preparing the report, unless some special, individual feature of an area makes some change imperative in order to achieve a logical presentation of the material. The beginner will need to study the outline carefully, together with special letters of instruction, particularly in regard to the section on productivity ratings, in order to be thoroughly familiar with the form and general treatment of the subject matter and the kind of data which must be available to him. A careful examination of recently published reports will be of great assistance. Conformity to the general style of these reports, even in spelling and punctuation, is necessary.

SOURCES OF DATA

It is evident from the outline that the information in the report is of two general kinds: (1) That relating to specific mapping units shown on the soil map; and (2) that dealing with the general conditions within the area. It can scarcely be overemphasized that the major attention and effort is to be given the specific information regarding individual soil types and phases, their relationship to growing plants, their response to different methods of management, and their utilization in the farm unit. For example, it is important to know the kinds and quantities of fertilizers used in an area, but it is far more important to know the kinds and quantities most economical for particular crops on particular soil types.

The principal source of specific information is the record of observations made in the field, in the notebook and on the map. These data must be supplemented by those available from farmers, experimental fields, and chemical laboratories. The soil surveyor must be certain that he has all available data, published and unpublished, including any obtained by other scientists in the area or on similar soil types in other areas. The necessary material for preparing the more general discussions is usually available, in considerable part, in the published reports of various governmental agencies.

FIELD DATA

The data collected in the area, embodied in the field notes and outlined on the soil map, form the most important part in the report and serve as a check on the accuracy of data drawn from other sources. The need for complete and accurate data is fully realized when the soil surveyor prepares the mapping legend and especially when he writes the final report.

Attention has been called to the necessity for complete descriptions of the soil profiles and the notation of all facts observed relating to the environment of the soil, such as vegetation, topography, and drainage, as well as to other factors which determine the capa-

bilities of the soil for use. Several detailed descriptions of every definite type of soil should be in the soil surveyor's notebook. It is highly important that estimates should be made of the present utilization of the soil, the proportion in cultivation, and the yield and quality of the various crops, as well as of the ability of the soil to produce crops not grown at present. It must be stressed that the fieldmen obtain and correlate, for purposes of the productivity ratings, detailed information as to average yields of crops under specified practices of management for the individual soil types. Aside from the difficulty of getting the farmer to correlate yields with soil type, there is also the need for the fieldman to evaluate the sources of his information.

It cannot be emphasized too strongly that notes must be taken on the spot wherever any observation of value is made, or any facts, based on actual experience, are obtained from farmers or others. Notes should also be taken on the important variations from type and on unusual soil developments. The beginner must guard against the common tendency to note the unusual with a failure to describe precisely the more common and general conditions. The soil surveyor must be ever on his guard against errors due to unconcious assumption gained from superficial appearances and from the literature. His notes should be of facts that he has definitely observed.

Suggestions have been given already as to the form of the field notes. The size, form, and arrangement of the field notebook is a matter of preference. It has not been found practicable to prepare an outline that can be used everywhere for describing soil profiles. The number of horizons and other characteristics of different soils vary so widely that such an outline could be used for only a limited group of soils. Several types of notebook are available, and the soil surveyor should procure those best adapted to his needs. Several systems of abbreviated nomenclature are in use for taking notes, and, although no particular one is definitely recommended, where many notes are taken the use of a standard system is often very helpful.

OTHER DATA

The chief of party must be certain that he obtains all available information bearing on the nature and use of the individual soil types as soon as an area has been assigned to him. The reports of areas previously surveyed and the reports of other researches, especially those from the State experiment stations and the United States Department of Agriculture, in which the soils and agricultural conditions are similar to those under observation, should be at hand as reference guides. Also the chief of party may gain considerable assistance in the interpretation and classification of the soils of the area from his supervisors and other scientists, who may be acquainted with the area or similar ones. During the progress of the survey, the mapping legend and soil-type descriptions must be revised and perfected from time to time as new information and data are accumulated. Other members of the party should be directed to collect and turn over to the chief of party information on those parts of the area in which they work, to supplement his observations.

All available publications on the geology of the region should be consulted. If these are not available at local libraries, they may be supplied from other sources. If the parent materials cannot be

identified in the field, samples should be submitted to the laboratory for examination. Similarly, data on the elevation of the area as a whole and of particular points are usually available from official publications.

The history of the county or area, including an account of its settlement and agricultural development, can be obtained usually from the writings of some local historian. If no such work is in existence, recourse must be had to the information supplied by old settlers or by residents who have had an interest in collecting such data. Since the recollections of truthful men often become inaccurate after a lapse of many years, estimates and opinions from such sources should be checked wherever possible by the data of the Census Bureau and the Weather Bureau. If all these sources fail, the salient facts of the history and development of the area often can be compiled from the data given in a history of the State.

Climatic data are furnished the fieldmen by the central office. The records of the Weather Bureau are tabulated for selected points within the area, or, if no records have been kept within the area, the data from the nearest stations outside with similar climatic conditions are used. Where climatic conditions are not uniform over an entire area, as in a mountainous country, or near large bodies of water, it will be necessary to secure information from local sources, especially facts relating to the occurrence of frosts and the length of the growing season.

Agricultural data along many lines can be obtained from the figures of the census. Tabulations of many subjects of interest are usually sent to the chief of the field party soon after work is started, but he must be certain that the latest available census data are in his hands. In recent years, the county agricultural agent has been able to furnish much reliable information on the types of farming in the area, the crops grown, varieties, yields, and other facts. This information can be interwoven with that taken more directly in the field from individual farmers. All statements must be evaluated and a check made with data of the Census Bureau, Weather Bureau, and other official sources. The information given by local farmers may have certain limitations, as it relates to crops growing on specific soil types. In some places, particularly in small towns, the local freight agent can give valuable information on the subject of agricultural products. Managers of storage warehouses and grain elevators and the secretaries of cooperative agencies often know within very close limits the character and volume of the shipments of products handled by them and their competitors.

WRITING THE REPORT

After the writer has considered carefully the general arrangement of the material for the report and the style of its presentation, he is ready to assort and classify his notes, abstracts, tables, and other data and group them under the proper subject headings as set forth in the outline. Although his field notes may contain carefully written descriptions of soils or features of the landscape that can be transcribed literally into the report, the author cannot make his report a disconnected assemblage of notes and tables. It is necessary that maps, field notes, and all supplementary data have sufficient

explanation and discussion in the text to bind the material into a harmonious unit.

In order to present a clear discussion relating to the uses, present and potential, of the soils of the area, certain factors that determine land utilization must be considered as indicated by the outline. The entire field of the agricultural geography of the region must be covered to the extent necessary to achieve this objective. As shown by the outline, the first section of the report includes brief discussions of certain physical and cultural features which influence, to greater or less degree, the present use of the land. In discussing the physiography of the area, the more important relationships between parent geological formations and dynamic geological processes and the resultant surface features and distribution of land and soil types are brought out in nontechnical language. Technical explanations of geological deposits in relation to parent material are included under the discussion of soil genesis near the end.

The second section is devoted to a discussion of climatic conditions, particularly with reference to those features which promote or limit crop production. The climate as a primary factor in soil development is treated in the section on the morphology and genesis of soils. The data of the Weather Bureau can be conveniently presented in tabular form, but interpretations and conclusions drawn from these tables and any peculiarities or variations in the climatic conditions of the area require explanation in the text.

The discussion of agricultural history and statistics should begin with an account of the types of farming practiced by the early settlers. The changes that have taken place in the kind of crops grown and in methods of cultivation should be traced briefly from the time of the first settlements to the present, and the causes for these changes should be explained. The rest of this section is mainly statistical, and its purpose is to present the basic facts of the agriculture. The kinds of crops grown, their production within the area, the number and value of the livestock, the kind and availability of labor, the size and tenure of farms, and other features of the agriculture are some of the items enumerated in the outline.

The discussion of methods and definitions includes a brief, general statement of the purposes of the soil survey and the methods by which the desired results are obtained. The purpose of this explanation is to give the reader the facts necessary to enable him to use the map and report. Technical details regarding methods beyond this are not included.

The fifth section, on soils and crops, is the most important part of the report and includes the principal part of the original work of the soil-survey party. This section is designed to present descriptions of the soils, to explain their individual capabilities for use, to bring out their relationships to one another, and to explain their response to management. The crops now being grown, the distribution of different crops over the area, and the degree to which soils determine this distribution should be explained. Included here are the specific yield data of crops on the individual soil types which are basic for the productivity ratings.

After the soils have been described and their utilization has been discussed, the question arises whether the soils identified in the area

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could not be utilized to better advantage. This subject is treated under the heading, Land Uses and Agricultural Methods. The results obtained on similar soils by the experiment stations and by farmers in other areas are reported.

The section on drainage, irrigation, or alkali reclamation should be given especial attention in the reports of areas where these subjects are important. In areas where these conditions of the land are incidental or of minor importance, a brief discussion of these subjects may be included in other parts of the report.

The discussion and table of productivity ratings will be prepared jointly by the author and the central office, as the productivity ratings reflect not only the specific productiveness of the local soil types, but also present comparative ratings on a national basis. The recent development of the concept of productivity ratings and accompanying questions demand a more detailed discussion in respect to each local situation than falls within the scope of this manual. It can be reiterated, however, that the chief of the field party is responsible for the collection of data on crop yields and adaptations and soil-management practices of the soil units shown on the map, in order that he may prepare a rating of them on a county basis.

The preparation of a report on the results of a soil survey that will meet the requirements of all readers is very difficult. The people who use these reports have a wide range of interests. The reports are designed to serve the needs of farmers, extension leaders, land appraisers, soil scientists, agronomists, and many others. In order to select and arrange the material of the report for the convenience of two principal groups of readers, two divisions of the report have been made. The facts of interest and of immediate practical use to the farmer and those who deal directly with him have been placed in the front and main body of the report. The writer should have constantly in mind the object of this more important part of the report, which is to present a picture of the area with its soils and their uses. The soil profiles should be described in some detail but in language as free as possible from technical expressions. Where the use of technical terms is unavoidable, their meaning should be briefly explained.

The second, and much smaller division of the report, which bears the heading Morphology and Genesis of Soils, deals with the characteristics and development of the soils from a more strictly scientific point of view. The usual procedure in this section is to trace the pedological history of the soil, beginning with the physical and chemical properties of the parent rock and the weathering processes by which the original rock was transformed into the parent material for soil. A knowledge of the factors of environment, such as climate, relief, and native vegetation, which govern the soil-forming processes, and the length of time during which these processes have acted to bring the soils to their present stage of development, are essential if the soil scientist is to understand the morphology of the soils of the area. If the soil scientist is given the factors that govern soil formation in a given area, he can predict within reasonable limits the character of the mature normal soil that will develop, even over rocks of widely different composition. In instances of immature soils, the composition of the parent rock exerts a greater residual influence.

The soil of the area that has had impressed on it the maximum force of the soil-forming processes is of special interest to the soil scientist. One or more of the soils which best represent the regional development should be described in detail. These descriptions will, in some respects, be a repetition of the more popular description of the soil given earlier in the report, but the horizons can be described more precisely, and the chemical and biological relationships can be pointed out. The intrazonal soils, which have developed under local conditions of environment, such as excessive moisture, should be briefly described and their relationship to the zonal soil of that region should be explained. The azonal soils, which, as a result of local conditions, have not reached maturity, should be briefly described, and the causes of their retarded development should be given. Supplementary data on the physical or chemical properties of the soils belong, as a rule, in this section.

The soil-survey report ends with a brief summary, in which the salient facts discussed in the report are enumerated. Perhaps a development of future reports may be a summary presentation in tabular form of the relationships existing between parent material, soil-forming processes, environmental conditions, soil characteristics, and productiveness.

COLLECTION OF SOIL SAMPLES

During the course of the soil survey and after the mapping legend has been prepared in its final form, samples of the important types should be collected for purposes of correlation, mechanical analyses, and pH determinations. Frequently it is necessary to collect samples for other laboratory investigations, under special instructions. The collection of the necessary samples should not be postponed until the survey is completed but accomplished during the course of the mapping after the soil definitions are well established.

Soon after the mapping legend has been prepared it is often advisable to collect samples of at least the principal soils for use at the field headquarters. These can be placed conveniently in shallow rectangular cardboard boxes with partitions arranged to scale according to the thickness of horizons, thus giving a miniature soil profile. Such samples are especially useful where the parties are large, where beginners are in the party, or where there are several soils previously not identified. Monoliths of actual soil profiles are very useful in educational work but are not necessary in the conduct of the soil survey. Several methods, most of which are modifications of the methods used by Professor Glinka and his coworkers, are in use. A discussion of the collection and preservation of monoliths hardly falls within the scope of this manual. Where such samples are required additional instructions will be furnished.

The greater part of the work attendant to the collection of soil samples is the preparation of a suitable excavation and a description of the soil profile. This has already been discussed in some detail (p. 72). The sketch in figure 15 illustrates a convenient method of preparing a soil profile for sampling. The measure of detail and care required depends on the use to which the samples are to be put. If a complete examination of the chemical and physical properties of the soil is to be made, it is of the utmost importance that

every precaution be taken to be certain that each sample is an accurate representation of the horizon from which it is taken, uncontaminated by foreign matter or other soil. The soil surveyor should be ever mindful of the fact that much time and expense on the part of other workers in the laboratory, in the greenhouse, and on the field experimental plot may be nullified if he neglects to collect samples in the proper way. Although great precaution may not seem necessary for the samples not intended for chemical or physical analyses, if the sample is worth collecting, in most instances it is worth the trouble of doing the job with care.

Proper samples, for chemical work especially, always should be taken from a fresh excavation. Except in the unusual instances of very recently exposed road cuts, no soil samples for any purpose other than immediate field identification should be taken from road cuts. Samples of rock and occasionally of parent material can be taken from road cuts, but not soil samples. There are several reasons why

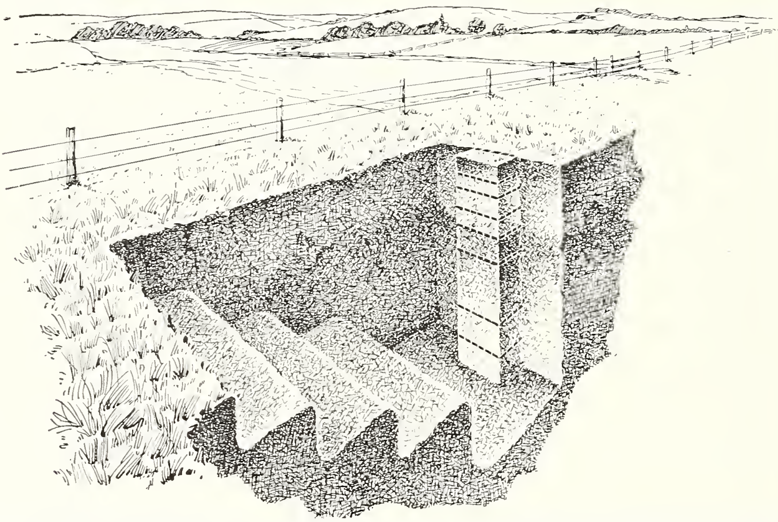

FIGURE 15.—Sketch showing a convenient method of preparing an excavation for collecting soil samples. The samples should be collected, so far as possible, one directly above the other.

soil samples from road cuts would be unsatisfactory. The dust, especially from a graveled road, quickly contaminates the exposed soil and the surface soil even if several hundred feet to the side. The native vegetation has usually been so disturbed along roadbeds that the soil is markedly altered, even though the land has not been plowed or otherwise mechanically disturbed. For example, it will be noted that the A_1 horizon of a Podzol is greatly thickened under the more luxuriant mesophytic vegetation, made possible by the greater light intensity along the roadway as compared to conditions within the forest. In the grassland areas the road and fence favor the accumulation of dust and other foreign matter.

As soon as a soil profile is exposed it is altered in many ways rather quickly. It is exposed to more rapid and thorough desiccation than previously. The alternate wetting and drying and freezing and thawing of the exposed soil markedly alter the natural

structural evidence. Further, the soil becomes more thoroughly oxidized than normally. Whereas in the natural soil the movement of water by both capillary action and that due to differences in vapor pressure is largely in a vertical direction, as soon as the profile is exposed movement becomes lateral and largely in one direction, leaving an increased concentration of soluble salts on the exposed surface. Frequently soil horizons that are soft or friable under natural conditions may become hard and indurated as the result of exposure.

After the profile has been exposed in a suitably located excavation, samples are collected by taking a core or block from each horizon in such a way as to get a representative portion. Where the parent material has been developed in place, samples of the underlying rock should be obtained. Except for the margins, which should be avoided, care must be taken to remove the soil uniformly from the entire horizon and not from either the upper or lower part alone. Samples should be taken, as nearly as possible, from a vertical section, one directly beneath the other. It is sometimes best to collect two or three subsamples from the upper and lower, or upper, center, and lower parts of thick horizons, for example, where the B_2 horizon of a soil being sampled for careful chemical study ranges from about 24 to 36 inches in thickness. Of course, if subhorizons are evident in the field they should be sampled as subhorizons and labeled subhorizons. But even where such horizons do not appear from the field examination, supplementary samples should be taken of each 12-inch section and labeled as subhorizons. In highly detailed studies of soil genesis subsamples representing only 1 or 2 inches of soil may be required.

Samples may be placed in clean cloth or paper sacks, or metal, cardboard, or glass containers. Where the soil is to be used for making miniature profiles, care must be taken not to destroy the structure, and moist samples can be placed in solid containers and allowed to dry with the minimum of distortion. The samples collected for the correlation files are usually placed in small clean cloth sacks, each carrying an identification card giving the date of collection, name of the surveyor, the location, the name of the soil type, the number of the soil horizon and its position in the profile, and a brief summary of the complete description. While the soil is moist, samples should be kept from contact with one another, or from anything except a clean surface. Unusually wet samples are best placed in containers and allowed to dry before being placed in the sacks.

Samples collected for chemical studies can be placed conveniently in heavy paper sacks such as those used for nails in retail hardware stores. A clean wooden box may be taken into the field, the half-filled sacks of soil set in the box and these lightly covered to prevent any contamination from the outside or from one another. The group of samples may then be allowed to dry in some convenient place. The moist soil will slightly weaken the paper, but later, after the soil is dry, each may be removed and placed in new sacks and carefully wrapped. Samples should be packed very tightly in strong boxes for shipment. Comparatively small boxes weighing less than 75 pounds when packed are best, in order that the danger of their wrapping becoming loose may be held to a minimum. The ad-

vantage of the paper sacks is their light weight and, compared to cloth sacks, their greater impenetrability to dust. If soils vary greatly in hydrogen-ion concentration or content of soluble salts or carbonates, samples placed in cloth sacks cannot be allowed to get into close contact with one another without danger of contamination.

Heavy cardboard containers, such as those used by retailers for ice cream, are equally as suitable as paper sacks but require somewhat more space for packing. Samples used for certain physical studies must not be allowed to lose their moisture, and these must be collected in metal cans with tightly fitted covers or in glass jars. Owing to their weight and danger of breaking, glass jars are not so suitable for shipment as metal cans.

Samples of highly organic soils, such as peat and muck, if collected when moist, as they usually are, should be placed in containers which can be sealed to preserve the original moisture. For ordinary purposes pint fruit jars are satisfactory, if sealing rubbers are used.

Unless otherwise stated it is always assumed that soil samples are of virgin soils. It is not always possible, however, to find good examples of certain soil types in the virgin state, and samples must be taken of soils under cultivation or in pasture. For purposes of defining the soil types as to their nutrient status and especially as to the variations which may be expected, it is sometimes necessary to collect a large number of supplemental samples. Frequently it is unnecessary that the complete profile be sampled, but only the surface soil (the plowed layer or its equivalent) and the one or two principal horizons underneath. For the lower part of the soil, it is much better to collect a sample of the principal part of the B horizon than one from an arbitrarily chosen depth. Samples collected at arbitrary depths cannot be compared and have little if any usefulness. Time should not be devoted to their collection except under special instructions.

For use in connection with the correlation of soils, samples by soil horizons should be taken of all soil types unless specifically directed otherwise. Samples of such land types as rough broken land and riverwash are unnecessary. Especially when new series are proposed, samples of the average or typical profiles of the soil types in the series are required. If there are any important variations within the series, as shown on the soil maps, additional samples of such variations are necessary. The characteristics of each soil type must be well in mind before precisely representative samples can be obtained. The type descriptions must conform to and be accurately illustrated by the samples for the correlation files. This is especially important for new soil types, even though their total area, as shown on the maps, be very small.

ESTIMATION AND MAPPING OF SALTS OR ALKALI IN THE SOIL

Soils having soluble salts in sufficient quantities to be toxic to plants are largely confined to arid and semiarid regions and to narrow coastal strips affected by tides in the humid regions. The amount and nature of salts in the soil will be reflected in the morphology of the soil profile but frequently not with sufficient

specificity as to the actual quantities which might be harmful to crop plants. This is especially true of young soils developed, or developing, from alluvial deposits. From the point of view of relief and other factors, these alluvial lands are frequently capable of use for crops if irrigated. The nature and amount of any soluble salts in the soil may be a matter of extreme importance in determining the feasibility of irrigation and the best use of such lands.

THE NATURE OF SALINE AND ALKALI SOILS

In much of the literature dealing with the utilization of soils containing salts, especially the American literature, there is some confusion regarding terminology. The confusion is primarily with the common names, such as "saline soils", "alkali soils", and "alkaline soils" and not with the names of the recognized morphological types.

There are recognized three intrazonal soil groups associated largely with the Pedocals: Solonchak, Solonetz, and Soloth, in the supposed order of their genesis, one after the other, and in the decreasing order of their content of total soluble salts. Within each group there is considerable variation and there are many transitional soils, such as the very common solodized-Solonetz. Although certain useful generalizations may be made regarding the chemistry of each of these groups, their identification is primarily a matter of soil morphology, and both the reaction and salt content may vary considerably.

The Solonchak typically is friable and massive (structureless) or has a crumb structure with no well-developed prisms; is light in color, generally high in soluble salts, and ordinarily not extremely high in pH value, although occasionally it is so, especially as this soil approaches the Solonetz. The Solonetz typically has a dark-brown or black B horizon and a hard prismatic or columnar structure; it usually has a relatively low total salt content but a high pH value, although not necessarily so, especially as the soil becomes solodized (the solodized-Solonetz) and approaches the Soloth. The Soloth has neither a high salt content nor a high pH value. These soil groups are defined on the basis of soil morphology, and the group names are used in reference to soil morphology, genesis, and classification, although they will need to be modified for specificity to "sodium interior Solonchak", "slightly solonized Solonchak", "solodized-Solonetz" and similar expressions.

These terms, however, are not in common use in agronomic literature in the United States, but other terms, generally less specific as to morphology, are frequently used. These include the expressions "saline", "alkali", and "alkaline", used alone or as modifiers of soil. These words are borrowed from chemistry and are, of course, subject to precise definition. They have had other meanings attached to them, however, in agricultural literature dealing with this group of soils. Unfortunately, the meanings are not uniform in the various parts of the country. For example, an "alkaline soil" in many places refers to any soil having a pH value greater than 7; in other places it refers particularly to a soil having a pH between 7 and 8.5, and again it is sometimes used in reference to soils over pH 8.5. Obviously the expression cannot have all three meanings. In the practical discussion of soils and crops in the soil-survey report, great care must be taken to define these words.

Where a certain local usage is very much entrenched, the term may be used in its local sense, even though that is not the best scientific usage, but the word should always be enclosed in quotation marks to indicate it has a special meaning. In the technical discussions the more accurate terms can be used.

Wherever practicable the terms should be used with their accepted chemical meanings. The expression "saline soils" is approximately equivalent to Solonchak (with a pH value less than 8.5) and may be considered as its common name. The term "alkali" should be restricted to such compounds as sodium carbonate and the expression "alkali soil", where used without a localized definition, restricted to soils with pH values over 8.5. The term "alkaline" should be used in its chemical sense in reference to any reaction greater than pH 7. The expression "alkaline soil" should be restricted to soils not excessively salty and not charged with alkali (over pH 7 but less than pH 8.5). Where local usage is contrary to these definitions and the expressions are used in other senses, they should be set off with quotation marks and clearly defined.

In some localities both saline and alkali soils are included under the expression "alkali soil." Occasionally this is modified to "white-alkali soil", roughly equivalent to Solonchak and saline soil, and to "black-alkali soil" roughly equivalent to alkali soil and only very roughly equivalent to Solonetz (but not to solodized-Solonetz). Where the expression "alkali soil" includes both general groups of soils, it becomes almost hopelessly broad, as there are important pedological and agronomic differences between the two. Occasionally the term "alkaline soil" is also used in reference to soils containing alkali. Ordinarily this term is not necessary at all, except in reference to the actual reaction. Calcareous soils, that is, those containing enough of the carbonates of the alkaline earth metals to maintain a mildly alkaline reaction, may be referred to as calcareous rather than alkaline.

The common salts that may accumulate in soils are of two general kinds: (1) Salts that are normally neutral in chemical reaction, predominantly the chlorides and sulphates of sodium and magnesium, with which may be associated the less common and less injurious chlorides of calcium and potassium and other salts of rare or infrequent occurrence. These neutral salts are sometimes known locally as "white alkali." Soils impregnated with such salts are saline soils or Solonchak and frequently have white incrustations. (2) The carbonate of sodium with minor associated carbonates which are chemically marked by being highly alkaline in reaction. Soils impregnated with such salts are alkali soils and because of the dark color imparted to the soil in the presence of moisture and organic matter they are sometimes known as "black-alkali" soils.

While both the neutral and alkaline salts are frequently intermingled and sometimes collectively designated as "alkali", use of the more exact and chemically correct terms of saline and alkali is necessary for clarity.

Salts may be localized in the surface soil or in some horizon beneath the surface soil, or more or less uniformly distributed through the soil profile, depending on soil texture, irrigation, drainage, and soil-moisture relationships. Accumulation of salts toxic to plants is indicated by a yellowing and unthrifty appearance of

crops, development of surface crusts and mulch, occurrence of slick and barren spots, or by the growth of salt-tolerant grasses and other plants.

THE ELECTROLYTIC BRIDGE AND ITS USE[14]

Quantitative determinations of the approximate salt content of soils in the field are made by use of the electrolytic bridge (fig. 16). The electrical conductivity of salts in solution is determined by measuring the electrical resistance of a prepared sample of soil inserted in the electrical circuit. Results are expressed in terms of percentage of total salts in the air-dry soil, readily convertible into terms of parts per 100,000 if desired.

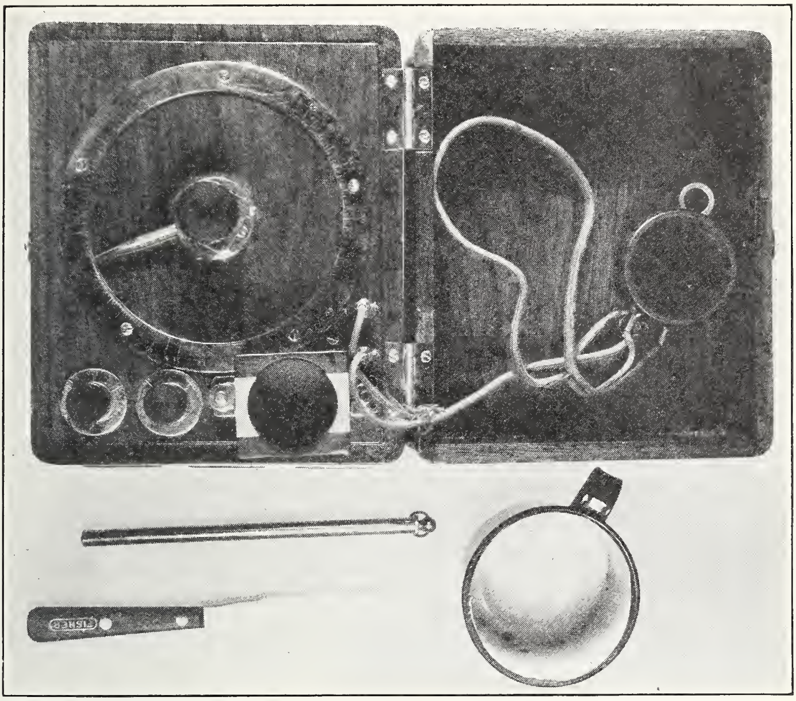

FIGURE 16.—Portable electrolytic bridge, with box open and cup in place ready for use. On the side are shown the mixing cup, spatula, and thermometer.

Electrical resistance is affected not only by the salt concentration but by the percentage of ionization of the salts and by the moisture content and temperature of the sample tested. In field operations, corrections are made for temperature and compensations for moisture content. The approximate salt content is determined from a curve or table representing average conditions in chemical character and relative proportions of the salts over wide areas.

Samples for salt determination must be taken carefully in selected locations. Some of these should be chosen to represent the salt content in places of maximum concentration and others to represent the lower or gradational degrees of accumulation. To obtain data for

[14] For a more detailed discussion of this technique see Davis and Bryan (5).

constructing a special map showing the distribution of salts and alkali, samples should represent average conditions of salt accumulation over areas of such extent and uniformity of character that they may be differentiated on the map. Samples of maximum salt accumulation on the immediate surface, including crusts and efflorescence, or localized in any horizon of the soil profile may be taken for special study. As a basis for mapping, samples of soils with weakly developed profiles are usually taken by 1-foot sections to a depth of 6 feet unless prohibited by impenetrable bedrock, hardpan, boulders, gravel, quicksand, or ground water. Samples of soils with well-developed profiles are taken by horizons. Samples are preferably taken with a spade, but the lower part of the soil may be sampled with an auger where the use of a spade is impracticable. Care must be taken to avoid contamination, especially where the auger is used.

Determinations of salt content may be made in the field at the time the samples are taken, or later in a laboratory or other convenient place where water is available for washing equipment. Frequently field testing is preferable, as the salt content of the soil is determined immediately and can be correlated on the spot with vegetation, drainage, relief, appearance of the soil, and any other factors which may be related. By this practice the surveyor can quickly form a sound basis for estimating the salt content of soil types and can draw boundaries of salt-affected areas with comparatively great accuracy. Where tests are made in the field, samples may be mixed on small squares of oilcloth and placed immediately in mixing cups or glasses. A bottle of distilled water for saturating the soil to be tested and a large can of water for washing equipment must be carried.

In some areas it is preferable to take the samples in cloth or paper sacks, carefully labeled, and make the tests at a convenient time. Where this system is used the surveyor may find it necessary to return to the field after the tests are made and visit the places where the samples were taken. Boundaries of salt or alkali phases can then be drawn on the basis of the test results and related facts. Difficulty may be experienced in mixing dried-out samples of heavy clays which are very tough and absorb water slowly.

Pebbles, fragments of roots, and other foreign material are removed from the sample before the determination is made, and a portion of the soil is placed in a convenient mixing cup. Distilled water is added slowly while the soil is mixed carefully with a spatula, until a condition of saturation is reached. The hard-rubber cup or electrolytic cell is filled with the saturated soil. The cell should be tapped gently to exclude air bubbles. The top is struck off with a spatula, leaving the surface smooth and the cell evenly filled. The cell is slipped into the electrical contacts, the circuit closed, and the bridge pointer turned back and forth, throwing into the circuit the 10-, 100-, or 1,000-ohm coils, as needed, until the buzzing in the telephone is reduced to a minimum. The product of the resistance of the coil and the bridge reading is the resistance of the soil. For example, if the 100-ohm coil is used and the scale reading is 1.25, the resistance of the soil is 125. If the extra 100-ohm test coil is used, 100 ohms is subtracted from the resistance obtained. The observed resistance must be corrected to a uniform temperature basis. The temperature

of the saturated soil in the cell must be determined at once by placing the thermometer in the cell and recording the temperature as soon as the mercury column has reached a stable position. Electrical resistance of irrigation, drainage, or other waters may be determined by substituting the water sample for the saturated soil.

INTERPRETATION OF BRIDGE READINGS

Resistance and temperature readings, soil texture, and field notes are recorded most conveniently in the special notebook arranged for this purpose. Resistance readings must be corrected to uniform temperature of 60° F. For this purpose table 2, taken from Bureau of Soils Bulletin 61, is used.

Table 2.—*Reduction of the electrical resistance of soils to a uniform temperature of 60° F.*

Degrees, Fahrenheit	Resistance when indicated resistance is—								
	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000
	Ohms	*Ohms*	*Ohms*	*Ohms*	*Ohms*	*Ohms*	*Ohms*	*Ohms*	*Ohms*
32	625	1, 250	1, 875	2, 500	3, 125	3, 750	4, 375	5, 000	5, 625
32.5	632	1, 264	1, 896	2, 528	3, 150	3, 792	4, 424	5, 056	5, 688
33	639	1, 278	1, 917	2, 556	3, 195	3, 834	4, 473	5, 112	5, 751
33.5	646	1, 292	1, 938	2, 584	3, 230	3, 876	4, 522	5, 168	5, 814
34	653	1, 306	1, 959	2, 612	3, 265	3, 918	4, 571	5, 224	5, 877
34.5	660	1, 320	1, 980	2, 640	3, 300	3, 960	4, 620	5, 280	5, 940
35	667	1, 334	2, 001	2, 668	3, 335	4, 002	4, 669	5, 336	6, 003
35.5	674	1, 348	2, 022	2, 696	3, 370	4, 044	4, 718	5, 392	6, 066
36	681	1, 362	2, 043	2, 724	3, 405	4, 086	4, 767	5, 448	6, 129
36.5	688	1, 376	2, 064	2, 752	3, 440	4, 128	4, 816	5, 504	6, 192
37	695	1, 390	2, 085	2, 780	3, 475	4, 170	4, 865	5, 560	6, 255
37.5	702	1, 404	2, 106	2, 808	3, 510	4, 212	4, 914	5, 616	6, 318
38	709	1, 418	2, 127	2. 836	3, 545	4, 254	4, 963	5, 672	6, 381
38.5	716	1, 432	2, 148	2, 864	3, 580	4, 296	5, 012	5, 728	6, 444
39	722	1, 444	2, 166	2, 888	3, 610	4, 332	5, 054	5, 776	6, 498
39.5	729	1, 458	2, 187	2, 916	3, 645	4, 374	5, 103	5, 832	6, 561
40	736	1, 472	2, 208	2, 944	3, 680	4, 416	5, 152	5, 888	6, 634
40.5	743	1, 486	2, 229	2, 972	3, 715	4, 458	5, 201	5, 944	6, 687
41	750	1, 500	2, 250	3, 000	3, 750	4, 500	5, 250	6, 000	6, 750
41.5	757	1, 514	2, 271	3, 028	3, 785	4, 542	5, 299	6, 056	6, 813
42	763	1, 526	2, 289	3, 052	3, 815	4, 578	5, 341	6, 104	6, 867
42.5	770	1, 540	2, 310	3, 080	3, 850	4, 620	5, 390	6, 160	6, 930
43	776	1, 552	2, 328	3, 104	3, 880	4, 656	5, 432	6, 208	6, 984
43.5	782	1, 564	2, 346	3, 128	3, 910	4, 692	5, 474	6, 256	7, 038
44	788	1, 576	2, 364	3, 152	3, 940	4, 728	5, 516	6, 304	7, 092
44.5	794	1, 588	2, 382	3, 176	3, 970	4, 764	5, 558	6, 352	7, 146
45	800	1, 600	2, 400	3, 200	4, 000	4, 800	5, 600	6, 400	7, 200
45.5	807	1, 614	2, 421	3, 228	4, 035	4, 842	5, 649	6, 456	7, 263
46	814	1, 628	2, 442	3, 256	4, 070	4, 884	5, 698	6, 512	7, 326
46.5	821	1, 642	2, 463	3, 284	4, 105	4, 926	5, 747	6, 568	7, 389
47	828	1, 656	2, 484	3, 312	4, 140	4, 968	5, 796	6, 624	7, 452
47.5	835	1, 670	2, 505	3, 340	4, 175	5, 010	5, 845	6, 680	7, 515
48	842	1, 684	2, 526	3, 368	4, 210	5, 052	5, 884	6, 736	7, 578
48.5	849	1, 698	2, 547	3, 396	4, 245	5, 094	5, 933	6, 792	7, 641
49	856	1, 712	2, 568	3, 424	4, 280	5, 136	5, 992	6, 848	7, 704
49.5	862	1, 724	2, 586	3, 448	4, 310	5, 172	6, 034	6, 896	7, 758
50	868	1, 736	2, 604	3, 472	4, 340	5, 208	6, 076	6, 944	7, 812
50.5	875	1, 750	2, 625	3, 500	4, 375	5, 250	6, 125	7, 000	7, 875
51	881	1, 762	2, 643	3, 524	4, 405	5, 286	6, 167	7, 048	7, 929
51.5	887	1, 774	2, 661	3, 548	4, 435	5, 322	6, 209	7, 096	7, 983
52	893	1, 786	2, 679	3, 572	4, 465	5, 358	6, 251	7, 144	8, 037
52.5	900	1, 800	2, 700	3, 600	4, 500	5, 400	6, 300	7, 200	8, 100
53	906	1, 812	2, 718	3, 624	4, 530	5, 436	6, 342	7, 248	8, 154
53.5	912	1, 824	2, 736	3, 648	4, 560	5, 472	6, 384	7, 296	8, 208
54	919	1, 838	2, 757	3, 676	4, 595	5, 514	6, 433	7, 352	8, 271
54.5	926	1, 852	2, 778	3, 704	4, 630	5, 556	6, 482	7, 408	8, 334
55	933	1, 866	2, 799	3, 732	4, 665	5, 598	6, 531	7, 464	8, 397
55.5	940	1, 880	2, 820	3, 760	4, 700	5, 640	6, 580	7, 520	8, 460
56	947	1, 894	2, 841	3, 780	4, 735	5, 682	6, 629	7, 576	8, 523
56.5	954	1, 908	2, 862	3, 816	4, 770	5, 724	6, 678	7, 632	8, 586
57	961	1, 922	2, 883	3, 844	4, 805	5, 766	6, 727	7, 688	8, 649
57.5	968	1, 936	2, 904	3, 872	4, 839	5, 807	6, 775	7, 743	8, 711
58	974	1, 948	2, 922	3, 896	4, 870	5, 844	6, 818	7, 792	8, 766
58.5	981	1, 962	2, 943	3, 924	4, 905	5, 886	6, 867	7, 848	8, 829
59	987	1, 974	2, 962	3, 949	4, 936	5, 923	6, 910	7, 898	8, 885
59.5	994	1, 988	2, 982	3, 976	4, 971	5, 965	6, 959	7, 953	8, 947
60	1, 000	2, 000	3, 000	4, 000	5, 000	6, 000	7, 000	8, 000	9, 000

TABLE 2.—*Reduction of the electrical resistance of soils, etc.*—Continued.

Degrees, Fahrenheit	Resistance when indicated resistance is—								
	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000
	Ohms	*Ohms*	*Ohms*	*Ohms*	*Ohms*	*Ohms*	*Ohms*	*Ohms*	*Ohms*
60.5	1,006	2,012	3,018	4,024	5.030	6,036	7,042	8,048	9,054
61	1,013	2,026	3,039	4,052	5,065	6,078	7,091	8,104	9,117
61.5	1,020	2,040	3,060	4,080	5,100	6,120	7,140	8,160	9,180
62	1,027	2,054	3,081	4,108	5,135	6,162	7,189	8,216	9,243
62.5	1,033	2,066	3,099	4,132	5,165	6,198	7,231	8,264	9,297
63	1,040	2,080	3,120	4,160	5,200	6,240	7,280	8,320	9,360
63.5	1,047	2,094	3,141	4,188	5,235	6,282	7,329	8,376	9,423
64	1,054	2,108	3,162	4,216	5,270	6,324	7,378	8,432	9,486
64.5	1,061	2,122	3,183	4,244	5,305	6,366	7,427	8,488	9,549
65	1,068	2,136	3,204	4,272	5,340	6,408	7,476	8,544	9,612
65.5	1,075	2,150	3,225	4,300	5,375	6,450	7,525	8,600	9,675
66	1,082	2,164	3,246	4,328	5,410	6,492	7,574	8,656	9,738
66.5	1,089	2,178	3,267	4,356	5,445	6,534	7,623	8,712	9,801
67	1,096	2,192	3,288	4,384	5,480	6,576	7,672	8,768	9,864
67.5	1,103	2,206	3,309	4,412	5,515	6,618	7,721	8,824	9,927
68	1,110	2,220	3,330	4,440	5,550	6,660	7,770	8,880	9,990
68.5	1,117	2,234	3,351	4,468	5,585	6,702	7,819	8,936	10,053
69	1,125	2,250	3,375	4,500	5,625	6,750	7,875	9,000	10,125
69.5	1,133	2,266	3,399	4,532	5,665	6,798	7,931	9,064	10,197
70	1,140	2,280	3,420	4,560	5,700	6,840	7,980	9,120	10,260
70.5	1,147	2,294	3,441	4,588	5,735	6,882	8,029	9,176	10,323
71	1,155	2,310	3,465	4,620	5,775	6,930	8,085	9,240	10,395
71.5	1,162	2,324	3,486	4,648	5,810	6,972	8,134	9,296	10,458
72	1,170	2,340	3,510	4,680	5,850	7,028	8,190	9,360	10,530
72.5	1,177	2,354	3,531	4,708	5,885	7,062	8,239	9,416	10,593
73	1,185	2,370	3,555	4,740	5,925	7,110	8,295	9,480	10,665
73.5	1,193	2,386	3,579	4,772	5,965	7,158	8,351	9,544	10,737
74	1,201	2,402	3,603	4,804	6,005	7,206	8,407	9,608	10,809
74.5	1,208	2,416	3,624	4,832	6,040	7,248	8,456	9,664	10,872
75	1,215	2,430	3,645	4,860	6,075	7,290	8,505	9,720	10,935
75.5	1,222	2,444	3,666	4,888	6,110	7,332	8,554	9,776	10,998
76	1,230	2,460	3,690	4,920	6,150	7,380	8,610	9,840	11,070
76.5	1,238	2,476	3,714	4,952	6,190	7,428	8,666	9,904	11,142
77	1,246	2,492	3,738	4,984	6,230	7,476	8,722	9,968	11,214
77.5	1,254	2,508	3,762	5,016	6,270	7,524	8,778	10,032	11,286
78	1,262	2,524	3,786	5,048	6,310	7,572	8,834	10,096	11,358
78.5	1,270	2,540	3,810	5,080	6,350	7,620	8,890	10,160	11,430
79	1,278	2,556	3,834	5,112	6,390	7,668	8,946	10,224	11,502
79.5	1,286	2,572	3,858	5,144	6,430	7,716	9,002	10,288	11,574
80	1,294	2,588	3,882	5,176	6,470	7,754	9,058	10,352	11,646
80.5	1,302	2,604	3,906	5,208	6,510	7,812	9,114	10,416	11,718
81	1,310	2,620	3,930	5,240	6,550	7,860	9,170	10,480	11,790
81.5	1,318	2,636	3,954	5,272	6,590	7,908	9,226	10,544	11,862
82	1,327	2,654	3,981	5,308	6,635	7,962	9,289	10,616	11,943
82.5	1,335	2,670	4,005	5,340	6,675	8,010	9,345	10,680	12,015
83	1,343	2,686	4,029	5,372	6,715	8,058	9,401	10,744	12,087
83.5	1,351	2,702	4,053	5,404	6,755	8,106	9,457	10,808	12,159
84	1,359	2,718	4,077	5,436	6,795	8,154	9,513	10,872	12,231
84.5	1,367	2,734	4,101	5,468	6,835	8,202	9,569	10,936	12,303
85	1,376	2,752	4,128	5,504	6,880	8,256	9,632	11,008	12,384
85.5	1,385	2,770	4,155	5,540	6,925	8,310	9,695	11,080	12,465
86	1,393	2,786	4,179	5,572	6,965	8,358	9,751	11,144	12,537
86.5	1,401	2,802	4,203	5,604	7,005	8,406	9,807	11,208	12,609
87	1,409	2,818	4,227	5,636	7,045	8,454	9,863	11,272	12,681
87.5	1,418	2,836	4,254	5,672	7,090	8,508	9,931	11,344	12,762
88	1,427	2,854	4,281	5,708	7,135	8,562	9,989	11,416	12,843
88.5	1,435	2,870	4,305	5,740	7,175	8,610	10,040	11,480	12,915
89	1,443	2,886	4,329	5,772	7,215	8,658	10,091	11,544	12,987
89.5	1,451	2,902	4,353	5,804	7,255	8,706	10,157	11,608	13,059
90	1,460	2,920	4,380	5,840	7,300	8,760	10,220	11,680	13,140
90.5	1,468	2,936	4,404	5,872	7,340	8,808	10,276	11,744	13,212
91	1,477	2,954	4,431	5,908	7,385	8,862	10,339	11,816	13,293
91.5	1,486	2,972	4,458	5,944	7,430	8,916	10,402	11,888	13,374
92	1,495	2,990	4,485	5,980	7,475	8,970	10,465	11,960	13,455
92.5	1,504	3,008	4,512	6,016	7,520	9,024	10,528	12,032	13,536
93	1,513	3,026	4,539	6,052	7,565	9,078	10,591	12,104	13,617
93.5	1,522	3,044	4,566	6,088	7,610	9,132	10,654	12,176	13,698
94	1,531	3,062	4,593	6,124	7,655	9,186	10,717	12,248	13,779
94.5	1,540	3,080	4,620	6,160	7,700	9,240	10,780	12,320	13,860
95	1,549	3,098	4,647	6,196	7,745	9,294	10,843	12,392	13,941
95.5	1,559	3,118	4,677	6,236	7,795	9,354	10,913	12,472	14,031
96	1,569	3,138	4,707	6,276	7,845	9,414	10,983	12,552	14,121
96.5	1,579	3,158	4,737	6,316	7,895	9,474	11,053	12,632	14,211
97	1,589	3,178	4,767	6,356	7,945	9,534	11,123	12,712	14,301
97.5	1,599	3,198	4,797	6,396	7,995	9,594	11,193	12,792	14,391
98	1,609	3,218	4,827	6,436	8,045	9,654	11,263	12,872	14,481
98.5	1,619	3,238	4,857	6,476	8,095	9,714	11,333	12,952	14,571
99	1,629	3,258	4,887	6,516	8,145	9,774	11,403	13,032	14,661

As an example, suppose the resistance at 78° F. to be 1,439 ohms. A resistance of 1,000 ohms at 78° is shown in the table as having a value at 60° of 1,262 ohms, one of 400 ohms (one-tenth of 4,000 ohms) an equivalent value of 505 ohms, one of 30 ohms (one one-hundredth of 3,000 ohms) a value of 38 ohms, and one of 9 ohms is equivalent to 10 ohms. The sum of these corrected values is 1,815 ohms, the corrected value for 60° as shown below.

Resistance at 78° F.	*Resistance at 60° F.*
1,000	1,262
400	505
30	38
9	10
1,439	1,815

Variations in soil texture and in the quantities of water required for saturation of the sample must be taken into consideration. Table 3 may be used for determining the approximate content of salts in soils of different textures, which contain predominantly chlorides and sulphates and little or no carbonates. The figures represent parts per 100,000, equivalent to 1,000 times the percentage, of total salts in the air-dry soil.

TABLE 3.—*Approximate amount of salts in soils containing predominantly sulphates and chlorides with given resistances*

Resistance at 60° F.	Sand	Loam	Clay loam	Clay	Resistance at 60° F.	Sand	Loam	Clay loam	Clay
	Parts per 100,000	*Parts per 100,000*	*Parts per 100,000*	*Parts per 100,000*		*Parts per 100,000*	*Parts per 100,000*	*Parts per 100,000*	*Parts per 100,000*
18 ohms	3,000	3,000	....	....	95 ohms	350	370	390	420
19 ohms	2,400	2,640	3,000	....	100 ohms	330	350	370	390
20 ohms	2,200	2,420	2,800	3,000	105 ohms	310	330	350	370
25 ohms	1,500	1,700	1,940	2,200	110 ohms	300	320	330	350
30 ohms	1,240	1,340	1,460	1,580	115 ohms	280	290	310	330
35 ohms	1,040	1,140	1,220	1,320	120 ohms	270	230	290	320
40 ohms	860	940	1,040	1,140	125 ohms	250	260	280	300
45 ohms	750	780	880	980	130 ohms	240	250	260	280
50 ohms	670	710	770	860	135 ohms	230	240	250	270
55 ohms	600	640	690	770	140 ohms	220	230	240	260
60 ohms	550	580	630	700	145 ohms	210	220	230	250
65 ohms	510	540	570	630	150 ohms	210	210	220	240
70 ohms	480	500	530	590	155 ohms	200	210	210	230
75 ohms	450	470	500	550	160 ohms	200	200	210	220
80 ohms	420	440	470	510	165 ohms	190	200	200	210
85 ohms	390	420	440	480	170 ohms	190	190	200	200
90 ohms	370	390	410	450					

When carbonates are present in more than small amounts the percentages of total salts for given resistances are materially increased. In pure carbonate solutions the increase in salt content at certain resistances, temperatures, and soil textures is nearly 100 percent. Comparable conditions are rarely met in the field, and table 3 ordinarily will give reliable results. Where carbonates are indicated or suspected they should be checked by phenolphthalein indicator or other colorimetric tests and the reaction recorded. The approximate salt content of soils containing carbonates is given in table 4.

TABLE 4.—*Approximate amount of salts in soils containing carbonates with given resistances*

Resistance at 60° F.	Sand	Loam	Clay loam	Clay	Resistance at 60° F.	Sand	Loam	Clay loam	Clay
	Parts per 100,000	*Parts per 100,000*	*Parts per 100,000*	*Parts per 100,000*		*Parts per 100,000*	*Parts per 100,000*	*Parts per 100,000*	*Parts per 100,000*
24 ohms	3, 000				130 ohms	410	530	590	720
25 ohms	2. 900	3, 000	3, 000		135 ohms	390	510	570	690
30 ohms	2, 100	2, 220	2, 220	3, 000	140 ohms	380	490	550	660
35 ohms	1, 640	1, 910	1, 910	2, 550	145 ohms	370	470	530	630
40 ohms	1, 420	1, 720	1, 740	2, 280	150 ohms	360	450	510	610
45 ohms	1, 240	1, 540	1, 560	2, 050	155 ohms	350	440	500	590
50 ohms	1, 300	1, 400	1, 420	1, 870	160 ohms	340	430	490	560
55 ohms	1, 000	1, 270	1, 290	1, 720	165 ohms	330	410	470	540
60 ohms	870	1, 160	1, 180	1, 600	170 ohms	320	400	460	520
65 ohms	800	1, 060	1, 080	1, 480	175 ohms	310	390	450	510
70 ohms	740	980	1, 000	1, 380	180 ohms	310	380	440	490
75 ohms	680	920	950	1, 290	185 ohms	300	370	430	470
80 ohms	640	860	900	1, 220	190 ohms	300	360	420	460
85 ohms	590	810	860	1, 140	195 ohms	290	350	410	450
90 ohms	560	770	820	1, 080	200 ohms	290	340	400	430
95 ohms	540	730	790	1, 010	210 ohms	260	320	380	390
100 ohms	510	690	750	970	220 ohms	240	310	370	360
105 ohms	490	650	720	910	240 ohms	210	280	340	330
110 ohms	470	630	690	870	260 ohms	190	260	320	310
115 ohms	450	600	660	830	300 ohms		220	280	290
120 ohms	430	570	640	790	340 ohms		180	230	240
125 ohms	420	550	610	750	380 ohms			200	200

In the earlier work of the Bureau of Soils a standardization curve and table were constructed for each area in the field, based on resistance readings of solutions of known concentration and successive dilutions prepared from representative crusts and samples of concentrated salts of the area to be surveyed. Chemical character as well as the concentration of salts, however, often varies widely from time to time in local areas, depending on fluctuating ground water and cultural and climatic conditions. Facilities for performing accurate standardization in the field are usually unfavorable, and it is now believed that more generally reliable results can be obtained from tables 3 and 4 based on careful laboratory manipulation. Should a standardization curve appear essential to represent unusual local conditions of salt accumulation, 10 or 12 crusts of strong salt concentrations from representative localities should be collected. It is recommended these be forwarded immediately to the laboratories where standardizations may be made. This may, however, be performed in the field in accordance with instructions given in Bureau of Soils Bulletin 61 (*5*).

Salt content in solutions or waters is determined in the same manner as in the saturated soil, using table 5, reproduced from that bulletin for interpolation and interpretation of resistance in terms of salt content.

TABLE 5.—*Approximate total salt content of water of given resistances at 60° F.*

Resistance 60° F.	Chlorides	Carbonates	Resistance 60° F.	Chlorides	Carbonates	Resistance 60° F.	Chlorides	Carbonates
	Parts per 100,000			*Parts per 100,000*	*Parts per 100,000*		*Parts per 100,000*	*Parts per 100,000*
30 ohms	750		140 ohms	141	200	340 ohms	50	71
35 ohms	670		150 ohms	132	187	360 ohms	47	65
40 ohms	595		160 ohms	124	176	380 ohms	44	60
45 ohms	525		170 ohms	116	165	400 ohms	41	55
50 ohms	460	460	180 ohms	109	154	450 ohms	35	46
55 ohms	400	425	190 ohms	102	144	500 ohms	31	38
60 ohms	355	395	200 ohms	96	138	550 ohms	28	32
65 ohms	305	375	210 ohms	91	130	600 ohms	25	27
70 ohms	265	355	220 ohms	87	122	700 ohms	22	23
75 ohms	230	335	230 ohms	83	116	800 ohms	20	
80 ohms	213	320	240 ohms	79	110	900 ohms	19	
85 ohms	203	306	250 ohms	75	105	1,000 ohms	18	
90 ohms	195	294	260 ohms	71	100	1,200 ohms	17	
95 ohms	188	284	270 ohms	68	95	1,400 ohms	16	
100 ohms	181	262	280 ohms	65	90	1,600 ohms	16	
110 ohms	170	250	290 ohms	62	86	1,800 ohms	15	
120 ohms	160	231	300 ohms	59	83	2,000 ohms	15	
130 ohms	150	213	320 ohms	54	77			

CARE OF THE ELECTROLYTIC BRIDGE

The electrolytic bridge is a delicate instrument and should not be subjected to unusual shock or jar. It may be carried safely in the field if placed in a container with liberal cushion or packing. The electrodes of the hard-rubber cell should be kept bright and free from grease, and the cell and bridge parts should not be allowed to become encrusted with mud or covered with dirt. Contacts should be kept clean and the circular bridge wire free from grit or dust by wiping with a soft cloth. The bridge should be provided with a live active battery and the buzzer or current interrupter adjusted to give a sharp reading. When thrown in circuit, the 100-ohm test coil should balance the 100-ohm comparison coil if the bridge is in proper adjustment. To make this test a piece of metal connecting the two contacts is substituted for the cell. Major adjustments and repairs should not be attempted in the field. When shipping or transporting the bridge long distances, the heavy electric cell in the lower compartment should be removed as it might become loosened and cause serious damage.

THE MAPPING OF SALT AND ALKALI PHASES

The location of samples taken for testing with the electrolytic bridge should be shown accurately on the map by a dot or a small cross. Each mark should be accompanied by the serial number of the sample as recorded in the field book.

In the absence of special instructions, which may be issued to meet particular conditions, the salt concentration of each sample is shown on the map in the form of a fraction, as $\frac{0.36}{0.64}$. The upper figure indicates the content of salts in the surface or surface horizon, the lower figure the average salt content to a depth of 6 feet, or depth of sampling. Ordinarily determinations are made of each horizon or 1-foot section separately, but if the distribution of salts

in the soil profile is relatively uniform, a saving in time may sometimes be effected by testing composite samples of two or more 1-foot sections.

The boundaries of salt-affected areas are indicated by broken lines. Both boundaries and data are shown in red ink. The definition of grades or degrees of salt accumulation to be differentiated in mapping salt and alkali phases, will vary with the character and conditions of salt accumulation, the physical character of the soil, the possible utilization of the soil, and the special objective of the survey.

In areas where local and infrequent salt accumulations occur, conditions may be indicated satisfactorily by merely recording the results of field tests on the map without any attempt to delineate boundaries. Ordinarily if an accumulation of salts presents a definite problem, delineation of boundaries between degrees of salt accumulation will be justified. It is now believed that the recording of the actual results of field determinations on the map, together with a somewhat wider latitude in delineating boundaries based on land-use capabilities, is preferable to the earlier system of attempting to map finer distinctions, defined on the basis of more exact percentages of salts in the soil.

Where salt accumulations occur in small scattered areas which may be either bare of vegetation or only sufficiently affected to reduce crop production, but in which only part of the land is affected, a "spotted" condition or complex may be indicated by the letter S and enclosed within a broken line delineating the general area in which the unproductive spots occur; or where the spots are too small for enclosure by boundaries a symbol is employed. These symbols are inked in red, both on the field sheets and the published map.

Where more uniform and extensive salt accumulations are developed, three or four degrees of concentration, which are of agronomic significance are indicated as "free", "slightly affected", "moderately affected", and "strongly affected." Supplemental maps are published in the soil-survey report showing these conditions. If only parts of the entire area are salty, the supplemental map need only include those parts, or if saltiness is comparatively unimportant, the condition may be shown with red symbols on the soil map and no supplemental map published.

Salt-free soils are limited to areas in which the average concentration of salts to a depth of 6 feet is less than 0.2 percent and of uniform distribution in the profile without localization in any one horizon within the feeding zone of plant roots. Surface concentrations exceeding 0.2 percent may be sufficient to limit or prohibit crop production, even though the average salt content to a depth of 6 feet may fall under the 0.2-percent limit.

Slightly affected areas contain relatively small amounts of salt, usually from 0.2 to 0.6 percent, so distributed in the soil profile as to threaten or sensibly decrease crop yields.

Moderately affected areas include concentrations of 0.4 to 1 percent of salt and represent conditions in which a serious decrease in yields and in the capabilities of the soil for agricultural use are reflected.

Strongly affected areas cover conditions in which salt concentrations usually exceed 0.8 or 1 percent and are associated with barren, encrusted soils, on which the use of the land for crops is prohibited.

The significance of the average salt concentration in the soil profile in determining the grades to be recognized in mapping and the capabilities of the soil for use is materially modified by any concentration of salts in the surface soil or other horizons within the soil zone of root development, and by soil texture and structure. These factors must, therefore, be considered in defining the grades or conditions of salt accumulation to be mapped, which are better determined in individual areas after the preliminary observations and field tests have been made.

Field boundaries and data should be shown on a secondary map having the same scale as the soil map, except where the affected areas are local and few. In these instances they may be added to the master soil map if this can be done without crowding or obscuring other boundaries and symbols. The presence of carbonates in appreciable amounts may be indicated by the letter C, in addition to other data recorded on the map. Other data may be obtained in the field under special instructions.

Complete field notes and descriptions of all special separations are required for the soil-survey report, as with any other separations shown on the map. The character of the native plant growth and of crop growth is always important, but it is especially important in connection with saline or alkali soils. The vegetation must be noted at each location where a sample is taken. A correlation often exists between certain plants and narrow ranges of salt concentration.

INSPECTION AND CORRELATION

The techniques involved in the identification, classification, nomenclature, and mapping of soil types vary according to the nature of the landscape and of the practical objective to be reached. At the same time it is highly important that similar soils be everywhere classified and named uniformly if the maps are to have their maximum usefulness. Also each soil surveyor should have the advantage of full information regarding the most accurate and efficient methods of work. Further, the maps, legends, and reports of every area must be carefully checked for accuracy before released for publication.

For the purpose of facilitating the technical supervision and inspection of the soil survey work in the United States there have been established five districts as shown in figure 1. The work of each district is under the technical supervision of an experienced soil scientist. Depending on the number and complexity of the areas under way within a district, less definite subdivisions may be under the responsibility of an assistant inspector. It is the duty of these supervisors to instruct the party chiefs regarding all technical phases of the work and to pass upon its accuracy.

INSPECTION

Ordinarily soil-survey areas are inspected at the beginning of a survey, at the end, and at one or more times during its progress, depending on circumstances. During the first inspection particular attention is devoted to the construction of the mapping legend. The

soil units to be mapped are determined and their descriptions carefully checked in the field. Plans for the construction of a base map of an adequate scale, for transportation facilities and similar details, are examined in respect to the conditions which obtain in the area. Any subsequent inspections during progress are devoted largely to the revisions in the descriptive legend and to examination of the field mapping. During the final inspection, the maps are thoroughly examined and the chief of party advised of all necessary revisions. The soil units shown on the map and described in the descriptive field legend are carefully rechecked in the field and a final correlation memorandum prepared by the inspecting scientist, assisted by the chief of party, indicating the recommended nomenclature to be used in the published report. The general outline for the report is carefully gone over by the inspector with the chief of party and a detailed outline prepared for the report of the particular area. A grouping of the soils for treatment in the report and similar details are decided, in order that the chief of party may prepare the final report promptly at the close of the field work.

The following outline is a reproduction of the report required of the inspecting official after each visit to a soil-survey area:

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF CHEMISTRY AND SOILS

SOIL SURVEY DIVISION

REPORT OF INSPECTION

Area______________________________ State__________________________________

Period of inspection____
(Preliminary, progress, final, for revision)

Number of previous inspections of this area_______________________________

Kind of survey____
(Detailed, reconnaissance, detailed-reconnaissance, or other)

Name of cooperating agencies____

____

Name of scientist in charge of field party_________________________________

Other members of party____

____
(Indicate organization of each man if other than Bureau employee)

____

____

In your opinion are each of these competent for the work to be done? If not, so state____

____

What transportation is available for the party?__________________________

State number of cars and trucks owned by: Bureau __, State __, and personal__

Is there ample transportation?____
(Yes or no)

How is the cost of this transportation arranged for?_______ _______________

Are there ample supplies and tools for carrying on the survey?______________

If not, explain____

Are the automobiles and other Government materials well handled by the men in the area? If not, explain____

____

____

In a concise statement give the purpose of the survey of this particular area, especially if there are any special demands for use of the map____________

____

____

____

What local organizations in the area have been interested in the survey?
____
With what results?____
____
Give the name and address of the county agricultural agent, if any__________
____
What sort of field notes are being kept by the party?______________________
____
____
Do all the mappers keep field notes or just the scientist in charge?__________
Does your inspection of the field notes indicate that sufficient notations are being made for purposes of preparing the necessary legends and reports?_____ (Yes or no)
If your answer to the above is no, give your suggestions____________________
____
____
Of what is the scale of the map?____________________________________
Is this scale adequate?____
How is the base map prepared?______________________________________
____
(Plane table, United States Geological Survey, etc.)
Do the men have available all previous surveys and control data?____________
If not, explain____
____
*Is the map tied to all available control data by United States Geological Survey, United States Coast and Geodetic Survey, and Army engineers?__________
*Where United States Geological Survey topographic sheets are used are alterations and revisions of the base map shown on a separate sheet?______________
*Are these shown accurately, especially new roads and railroads, or are they merely indicated?____
Do the men understand that errors are to be located and corrected where possible but that small closure errors are not to be "adjusted" in the field?____
Are the conventional signs used in conformity with those adopted by the United States Board of Surveys and Maps?___________________________
If not, are all departures clearly indicated?_____________________________
*Are streams named throughout their courses?_____________________________
Does your inspection indicate that the base map being used or being prepared is adequate for the soil survey?_________________________________
If not, what are your suggestions?__________________________________
____
*The maps are (write each man's name after proper word) :
Very neat____
Neat ____
Easily legible____
Barely legible____
Illegible ____
*Are the following shown on each sheet:
Name of area?____
Names of field men?____
If more than one man worked on the sheet, and especially if more than one man ran the traverse, is the portion of the work done by each man indicated by sketch?______________________________________
Scale of map?____
Magnetic north-and-south line?_______________________________
*Do the letters or symbols on the map correspond with those in the legend?_____
*Is every symbol used on the maps defined in the field legend?________________
*Are the maps properly copied with ink as the field work progresses?__________
*Are the individual sheets properly joined as to roads, streams, soil boundaries, etc.?____
*If not, what is your suggestion?___________________________________
____
Does the party have available plats of the General Land Office survey?________
Is the map properly tied to the Land Office survey?_________________________
*Are located section corners and quarter-corners indicated as such?__________
*Are the municipal boundaries of villages, towns, and cities shown?__________

*Are towns and villages shown on one sheet in their entirety and without large closure errors?________________________

*Are the maps properly joined to previous soil surveys of adjoining areas?____

____

*If not, explain__________________________________

____

*Does your inspection indicate that the soil boundaries are accurately drawn?__

____

*Does your inspection show that equal care is taken distant from roads as near roads?____________________________

*If your answer to either of the above is no, explain your suggestions________

____

Is the soil classification logically constructed?____________________________

Explain any inconsistencies__________________________________

____

____

Has a full descriptive legend showing *all* mapping symbols and describing *all* soil separations been furnished each mapper?______________________________
(Yes or no)

Does your inspection show this legend to be complete and accurate?___________
(Yes or no)

If your answer to either of the above two questions is no, explain the action taken__________________________________

____

Are the men instructed as to the proper way of collecting soil samples for correlation?________________________________

Who is writing or is expected to write the report?__________________________

What progress has been made toward preparation of the report?_____________

When do you expect the map to be completed?_____________________________

What provision is being made for an extra copy of the map for the State?_____

____

When do you expect the report to be completed?____________________________

State total number of reports and maps of the area which should, in your opinion, be printed________________________________

Submit a list showing all separations, including phases and any special features (to be attached)________________________________

____

Remarks and recommendations for improvement (include brief statement of changes that you directed the men to make)______________________________

____

____

Date reached area________________________________,
(Date and time)

Date left area____________________________________.
(Date and time)

__________________________________.
(Signature of inspecting official)

Date________________________

NOTE.—It is important that all questions be answered where the work has been started. Certain questions, marked with an asterisk (*), cannot be answered where field work has not been started, but in these instances also it should be made certain that the men are properly instructed.

CORRELATION

The correlation of soils refers to the procedure for the determination of the final names to be given the mapping units shown on the published maps. This is accomplished by the correlation committee, consisting of the district inspectors, one of whom is chairman, from a study of the type descriptions and samples submitted by the chief of party and the final correlation memorandum of the inspecting scientist in relation to standard samples and descriptions of established soil units. A large part of this work might be called more appropriately "collation" since the purpose is to determine the nomenclature of similar soils. It is equally important to determine

which soils in the new area are similar to ones already established and which are entirely new and must be given new names and a place in the general system of classification.

The final correlation of the soils of an area involves both an adjustment of the local classification to conform to the principles of soil taxonomy and the fitting of the local classification into the framework of the Nation-wide system of nomenclature. The first step involves the proper adjustment of the categories so that distinctions which have been mapped may be designated properly as soil types, phases, complexes, or land types. In the adjustment of the nomenclature and as a matter of economy in publication, it is sometimes necessary to combine types or phases which have been differentiated in the field mapping. At times such combinations may be made because of a very small total area of the type mapped. From a strictly scientific point of view, such combinations are not desirable and when made, care must be taken that the characteristics of the soil which has been eliminated from the map by inclusion with some other soil be described fully in the report.

All data bearing on the problem must be given consideration. These data include the field maps, the descriptive field legend, the report, the soil samples, and the recommendations of the inspector, as well as available results of laboratory examinations. In addition, it is necessary to have an estimate of the total area of each soil type and phase which appears in the legend. These estimates should be submitted with the soil legend accompanying the field sheets. It is important to the correlation committee that the soil nomenclature be uniform throughout and that the soil names used in mapping the legend correspond to the soil names used in the report, in the descriptive legend, and in the inspector's correlation memorandum. It is helpful to append the field symbol to the soil name in each instance.

This work of correlation requires careful judgment and a consideration of all available data from the field, frequently supplemented by laboratory determinations. After the correlation committee has made its findings the chief of party and other interested scientists are advised of the results and given an opportunity to express suggestions for any changes supported by additional data. After receiving approval of the scientist in charge of the organization, the final report of correlation is adopted and copies are furnished those preparing the map and report for publication. Especial care must be taken to insure the correctness of this work. The value of the mapping depends to a great degree on the correctness of the nomenclature.

During the development of soil nomenclature in the United States tremendous advances have been made in soil science, both fundamental and applied. Many of the earlier established soil series covered such a wide variation of characteristics that any definition of their capabilities for use lacked the necessary specificity for the demands of practical application of the results to individual tracts of land. These had to be split into more exactly defined units, and some had to be redefined and a few abandoned altogether in subsequent mapping. Perhaps a few soil series are not yet defined as precisely as they should be and as they will need to be ultimately.

Naturally these changes have brought about some confusion when old surveys are compared to new ones. Although no one would dare to suggest that the classification of soils, or of any other natural bodies for that matter, is at present perfect and complete, and that no future changes will be necessary, the nomenclature is now well developed and established.

In connection with the correlation of soils is the problem of grouping mapping units into higher categories, both from the point of view of the technical aspects of classification and the more practical point of view of the capabilities of the soils for particular crops. This work also is the responsibility of those scientists engaged in the correlation of soils, but a description of the methods and techniques involved lies beyond the scope of this manual.

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